REVIEW ARTICLE

A Home Toolkit for Primary Prevention of Influenza by Individuals and Families

CME online

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ABSTRACT

An influenza pandemic can overwhelm the capacities of hospitals, clinics, nursing facilities, and emergency services. The likelihood is that most of the individuals who are stricken will be cared for at home, and there is strong evidence that in-home caregivers bear a disproportionate risk of becoming infected. We reviewed the scientific literature after 2000 to identify steps that in-home caregivers can take to reduce the chances that they and other household members will become infected in the home. Personal hygiene, common masks, and technologies including air filters and UV light each offer incremental benefits, and in combination are expected to reduce a portion of the risk that household members face when caring for a member who has become infected. In pandemics and even seasonal epidemics, seemingly small steps can literally mean the difference between life and death, especially for in-home caregivers.

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Key Words: influenza, flu, pandemic, nonpharmaceutical interventions

In June 2009, the World Health Organization declared a full-fledged pandemic of a novel strain of influenza named A (H1N1), whose genome included material of swine, avian, and human origin.[1] The number of cases grew rapidly to reach millions worldwide. As the pattern of illness evolved, coming to resemble more of a seasonal outbreak than past pandemics, we escaped the severity of a raging pandemic influenza that could have rapidly overwhelmed the capacities of hospitals, clinics, nursing facilities, and emergency services.[2-5] In the future, we may not be so fortunate.

We must prepare for the likelihood that most of the individuals who are stricken by pandemic influenza will be cared for at home by loved ones. This issue has been raised by the Agency for Healthcare Research and Quality: "In the event of an influenza pandemic, because of anticipated shortages of health care professionals and widespread implementation of social distancing techniques, it is expected that the large majority of individuals infected with the influenza virus will be cared for in the home by family members, friends, and other members of the community—not by trained health professionals."[6]

The risks to those living in but not yet infected with influenza in a stricken person's home need to be recognized and mitigated. Two studies that examined data on deaths caused by influenza concluded that spouses sharing the household of an infected spouse experience approximately twice the population-expected number of deaths from infection, a relative risk ratio higher than that of any blood relatives.[7,8] In other words, caregiving spouses are at great risk of becoming infected from their infected husbands or wives. These are alarming statistics and not widely known. Researchers in these studies focused on genetic predispositions to becoming infected and did not emphasize these findings because wives and husbands are, by definition, genetically unrelated.

How can we reduce the risks to family members caring for those in their households who are ill with influenza? It is a matter of educating the public and empowering them to adopt straightforward behavioral measures that can reduce the chance of becoming infected. The opportunity for education is at hand, but although many public health preparedness plans recognize that vaccines and antiviral drugs will be unavailable or insufficient, and some even outline various social-distancing measures that could be implemented, far too many miss a huge opportunity to empower individuals and families to take steps that could greatly reduce the adverse effects of a pandemic.[9]

Many health authorities expect that caring for people with influenza at home to be a substantial component of any response to pandemic influenza.[6] Information that focuses on symptom recognition and on care that addresses symptom relief through the use of over-the-counter medications can be found easily.[10,11] Several products related to nonpharmaceutical interventions (NPIs) could be adopted for home use at relatively low cost. Most are easy to implement and would require little effort beyond the initial purchase and installation. Health authorities have commonly offered only limited guidance on these interventions, perhaps because their effectiveness has proven difficult to study. They do not lend themselves easily to randomized trials or rigorous observational research. In an effort to inform the dialogue, we conducted a systematic review of a set of NPIs

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that could offer great benefit in reducing the spread of infectious illness within indoor spaces, such as households.

LITERATURE REVIEW

We conducted a systematic review of the scientific literature to elucidate what is known about the effectiveness of the following NPIs in reducing the spread of infectious illness: hand hygiene, surgical masks, air filtration and ventilation, disinfecting UV light, and temperature and humidity control. To capture published studies that may have appeared in outlets outside medicine and the life sciences, we searched 20 databases that were available in our libraries that covered the natural and social sciences, engineering, and management. The databases included PubMed, Web of Science, Social Science Citation Index, and EconLit.

Our aim was to identify credible information from studies that included laboratory experiments or simulations of virus transmission, human studies of infectious disease transmission in closed indoor spaces, and databased, historical reports of the effects of NPI use in past outbreaks of respiratory illness. The search terms and phrases used were based on the names of the NPIs listed above. The original search was conducted in early 2009 and focused on articles published in 2000 or later but also captured a number of seminal reports that had been published earlier. A second search was conducted in August 2010 to ensure that we had identified additional relevant information that was reported in the context of the recent H1N1 outbreak.

Using this process, we identified approximately 200 articles, and among these, we focused on a subset of 40 that we considered especially relevant to our objectives. Each of the articles we drew upon to formulate our recommendations met some or all of the following criteria: published in peer-reviewed journal, captured in a published systematic review, widely cited in later articles, and referenced in government publications. In addition, all of the articles we used contained insights that, in our judgment, followed from research conducted with suitable scientific rigor. We also examined the lists of references that appeared in these publications. The subset included 10 systematic reviews, each of which addressed some of the NPIs whose effectiveness we were examining. The original research covered in this body of work reported a range of quantitative metrics that could be used to assess the effectiveness of the selected NPIs. We were interested mainly in the "broader picture," qualitative insights supporting the plausibility that each NPI offered benefits in mitigating the spread of infectious disease within a home.

HOW THE INFLUENZA VIRUS IS TRANSMITTED

The mechanism of virus transport from its release to when it infects a new host is still not well understood. Three different possible mechanisms of spread are commonly described: direct contact, indirect contact, and airborne spread.[12] A review of how the influenza virus spreads helps emphasize the preventive value of NPIs.

TABLE 1

Possible Benefits From Nonpharmaceutical Interventions

	Can Block?		
Intervention	**Large Droplet**	**Airborne**	**Droplet Nuclei**
Hand hygiene	X	?	?
Masks	X	?	?
Ventilation/HEPA filtration	X	X	X
Exhaust fan	X	?	?
UV light	X	X	X
Temperature, humidity control	X	?	?

HEPA=high-efficiency particulate air; UV=UV.

The virus is spread by the emission of virus-containing particles from the nose and mouth of ill individuals when they cough, sneeze, talk, or breathe. Some of these particles may be aerosols that are suspended in air for long periods and can be carried in the atmosphere directly to susceptible individuals.[13] Severely limited ventilation, often found in enclosed spaces such as patient care rooms, makes it much easier for these aerosols to intensify, be inhaled, and directly infect the tissues of others' lower respiratory tracts.[14]

Large emission particles are often launched by coughs or sneezes. Laden with virus, the particles travel short distances and may either directly contact a susceptible person or settle on surfaces.[12,14] Once deposited on a surface, the influenza virus can survive for up to 48 hours, and subsequently infect the upper respiratory tissues in the eyes, noses, mouths, and throats of healthy individuals who touch these surfaces and then touch their faces.[15] Some of the moisture in large particles can evaporate, producing smaller particles called droplet nuclei, which pose risks similar to those of other smaller particles that remain airborne.[12] These small virus-laden particles can remain suspended for long periods of time, travel with air currents, be inhaled, and infect upper respiratory tissues.[16,17] They may settle eventually and contaminate surfaces, posing a risk for secondary contact transmission.

Once influenza-containing particles are released into the environment, the spread of influenza is dependent on the physical and biological decay of the influenza virus. Physical decay refers to mechanisms that remove viruses from the environment (ie, filtration or dilution). Biological decay results from factors that inactivate the virus and prevent it from causing infection (ie, relative humidity, disinfectants, UV [UV] C light). The ability of virus-containing particles to infect susceptible individuals decreases with NPIs that use these decay mechanisms and other interventions that block or remove the virus. These interventions include disinfectants, mechanical barriers, and negative air pressure, which can reduce the chances of infection. Table 1 summarizes the possible benefits offered by these NPIs according to whether each has the capability to block large droplets, droplet nuclei, or airborne transmission.

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NONPHARMACEUTICAL REMEDIES FOR THE HOME

Hand Hygiene

Hands are the common intermediary between infected objects or surfaces and the entry points into the body. Hand hygiene, therefore, offers great potential for preventing infection. Empirical studies, particularly in hospitals, day care centers, and schools, suggest that diligent washing and hand sanitizing can reduce infections by 20%-95%.[18-24]

Evidence and common sense suggest that the more time we spend washing our hands, the more pathogens we remove. A period of 20 seconds seems suitable for removal.[25] Common detergent-based soaps work, but alcohol-based hand sanitizers can be highly effective disinfectants because alcohol denatures virus-associated proteins.[26] One study showed that a 95% ethanol-based rub reduced the influenza virus to undetectable levels after 30 seconds of use, by which time hands would be completely dry.[27]

Hand soaps and sanitizers are inexpensive, pose minimal risks, and have been the object of widespread media campaigns, but how many people apply them for 20 seconds each time? Wearing surgical-type gloves when entering a patient care room also offers some protection to healthy members of a household. Of course, people wearing gloves must not touch their mouths, noses, or eyes while wearing them and must dispose of the gloves after each use.

Surgical Masks

The home use of common surgical masks provide a modest benefit in pandemic influenza.[28-30] Although they probably do little to block fine aerosol transmission,[31] they may block some large, virus-containing particles that are emitted when a sick person sneezes or coughs. Some evidence suggests that a mask worn by an infected person reduces the speed of the air expulsed from the mouth or nose, limiting the distance traveled by large particles.[32] A mask may prevent a healthy person from inhaling some large particles. Perhaps more significant is that it is much more difficult for a well person wearing a mask to transfer any virus particles from the hands to the more vulnerable nose and mouth and prevent secondary contact transmission.[33]

Air Filtration and Ventilation

Empirical observations show a strong correlation between increased rates of infection and poorly circulated or ventilated air.[14] Evidence also points to the effectiveness of specialized air handling and ventilation in reducing potential aerosol transmission of influenza.[14] Some products are available at low cost and are easy to use.

The concentration of airborne virus particles is reduced with air circulation through a filter and/or with fresh air entering the room from outside.[34] High-efficiency particulate air (HEPA) filters, typically costing ≤$100, work in most homes that are heated by forced-air or other climate-control and ventilation systems, and can remove nearly 98% of particles ≥0.3 μm.[35] A portable air purifier can be used for circulation in homes heated by other methods and can be purchased for $100-$500 per unit.

Even a simple fan facing out the window of an enclosed patient care room can help remove the influenza virus by creating a slight negative pressure differential compared to that in other rooms in the home. With the room door slightly ajar, an outward-facing fan would transport air from the rest of the home though the patient care room to the outside. This action is presumed to reduce the leakage of infected air when the patient care room door is opened to other parts of the home,[36] and it reduces the concentration of airborne virus particles in the patient care room. This cleansing of the air presumably lessens the density of any aerosol virus particles, thereby reducing the chance of infecting a caregiver in the patient care room.

UV Light

The C wavelength range of UV light has been found to be antimicrobial, with the potential to disinfect the air by inactivating virus-containing aerosols.[37] A hospital study found 2% and 19% rates of influenza in 2 comparable buildings with and without UV lights installed, respectively.[38] The effectiveness can double when there is a continuous source of cold air at the ceiling level, which sinks as warmer air rises and thus increases air circulation, creating greater exposure to the UV irradiation. A large room or ceiling fan also supports this effect.[39] Combining an exhaust fan, as described above, with another in the room to promote circulation may work the most effectively.

Installation of a UV light inside an existing forced-air heating, ventilation, and air conditioning system may provide the best results, but it could require reconfiguring the system, making installation expensive. A better option to mitigate influenza transmission within a household may be a portable, stand-alone air purifier with a HEPA filter that contains a UV lamp. Available units are in the $180-$370 range and commonly incorporate fans that funnel air from the room through the contained HEPA filter, expose it to the disinfecting UV lamp, and subsequently move the disinfected air out of the unit and into the room. In this way, the household can benefit from the use of UV light and HEPA filter air purification with minimum overhead costs and the advantage of portability within the home.

Temperature and Humidity Control

Many influenza virus–survival studies and animal transmission models show that higher levels of both temperature and relative humidity are associated with reduced virus stability and are consistent with stronger and more effective host immune defenses, particularly in the early stages of the development of infection.[40] Home room temperature typically can be regulated using a thermostat, within a narrow range, while continuing to maintain comfort. Humidity levels, which are typically low in the indoor environment during influenza season and conducive to influenza survival, can be increased with portable humidifiers. Desired levels of humidity (40%-60%) can

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be achieved through the use of portable humidifiers, which can be purchased for $25-$50.[41]

Bathrooms

Transmission of diseases found in bathrooms has long been recognized as a substantial risk. These shared spaces tend to be used disproportionately by people who are unwell and who can contaminate surfaces and ambient air.

Even flushing toilets can cause significant numbers of virus particles to become aerosolized, increasing risk of infection.[42] Although virus particles are associated with intestinal disorders, severe acute respiratory syndrome (SARS) was found in human feces, and a toilet flushed by a SARS-infected individual in a Hong Kong high-rise apartment building with faulty plumbing caused scores of other residents to become infected.[42,43] Novel H1N1 influenza has caused vomiting and diarrhea in about 40% of those infected and has been found in human intestines.[44] These circumstances may be special, but they are still worth considering when someone infected with influenza is cared for in the home.

Diligent preventive behavior would suggest dedicating a single bathroom to the exclusive use of the sick person in homes with multiple bathrooms. Consistent with our earlier discussions, certain other protective measures that pose little cost or risk may be helpful. The bathroom window should be left partly, if not completely, open. A ceiling exhaust fan, if present, should be kept in continuous operation. Being careful to avoid infection by wearing gloves and keeping air circulating outward, one should wipe down the patient care room with a virus-killing disinfectant at regular intervals to decontaminate surfaces.[7]

COMMENT

Consensus is growing that rapidly moving outbreaks of influenza would be susceptible to public health measures and individual behavioral changes if implemented quickly and with vigilance. "An important component of the current pandemic planning strategies in the United States and many other countries is to keep ill persons out of the hospital and have large numbers of them cared for at home, with the idea of avoiding the amplification of infections in hospitals seen with SARS in 2003 and with a range of other modern epidemics."[45] Benefits would not be limited to global pandemics, and could prove useful in mitigating the transmission of seasonal influenza.

Each NPI discussed in this article could be a part of what we call "family-friendly" packages. Hand hygiene, use of surgical masks, air filtration and ventilation, germicidal UV light, and temperature and humidity control potentially offer great benefits in reducing the spread of illness within the home. Even if it is difficult to quantify the potential benefits of taking these steps, each measure contains a plausible rationale for how it would help. The environmental changes resulting from their implementation do not appear to pose measurable risks. The implementation costs can be sufficiently low that even a modest level of incremental benefit would make them attractive for individuals and families.

BOX

Influenza Dos and Don'ts

Things to Do and Not to Do

- Wash hands frequently with hot water and soap for at least 30 seconds and dry thoroughly, particularly after shaking hands or coughing.
- Try not to touch your face with your hands.
- Practice careful bathroom etiquette.
- Avoid direct hand contact with surfaces that are likely to be contaminated.
- Hold meetings via telephone and e-mail when possible.
- Read and study http://www.ifh-homehygiene.org/2003/index.html

TABLE 2

Suggested Home Care Influenza Kit

Items to Purchase	Typical Cost, $
Detergent-based soap	10
Alcohol-based hand sanitizer	10
Window fan	40
UV light unit (some with HEPA filters)	180-370
HEPA filter system	0-600
Tissues	5
Face masks (25)	10
Total, approximate	250-1000

HEPA=high-efficiency particulate air; UV, UV.

Our proposal goes well beyond existing guides and checklists (eg, www.pandemicflu.gov) that advise how to prepare for pandemics. An individual caring for a sick loved one is performing a role that is similar to that performed by a professional health provider, and, unless ameliorative steps are taken, he or she faces significant risk of being infected. The home caregiver would benefit from the same precautionary measures that are used in the hospital care setting. Although some of our suggested interventions are standard measures within the health care/hospital setting, we propose extending existing recommendations to incorporate a small set of hardware-embodied interventions. A suitable air filter and exhaust fan would be 2 of the components; these could be used alone or in combination with UV light. These interventions can be implemented easily in the home, and families could benefit passively after a modest initial investment of time and money (as low as $250; Table 2).

Health officials at all levels should publicize all of the NPIs mentioned in this article as examples of actions that individuals can take to prepare for an influenza pandemic. Merely announcing or promoting them will not be sufficient to ensure their adoption, however. Planning is needed to ensure that the components of these family-friendly packages are available in ad-

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equate quantities to meet public health needs. Attention also should be paid to whether there should be special means of distribution during a public health emergency.

The packages must include fact sheets written in plain language, with details of how to use each option. Local print and electronic media can be enlisted to help disseminate this information. Establishing "auditing" organizations such as those that recommend ways to reduce energy consumption in private homes could go a long way toward assisting families in implementing these options.

Although the costs associated with adopting these NPIs will be modest for many families, they are certain to be outside the reach of others. Subsidies from prominent employers, local merchants, and some government agencies could be arranged to make these interventions accessible to families of lesser financial means. Emergency government funding, for example, through the Federal Emergency Management Agency for natural disasters, could be expanded to include assistance to people to prepare for pandemics. Even if a family purchases and uses all of the suggestions/products we propose, the total cost is a fraction of a single day of hospitalization. This fact alone argues for subsidies for those who cannot afford these steps, because the ultimate cost likely will be reduced.

Existing pandemic preparedness plans simply do not go far enough to encourage changes in individual behaviors to reduce the spread of disease. The commonsense measures we propose would help create an environment within the home that is less conducive to the spread of viral illness and would even help prevent commonly and seasonally occurring infectious diseases.

The risks to in-home caregivers, who are often spouses of those who are ill, must not be underestimated: "The significantly elevated RRs (Relative Risks) observed in spouses must be assigned entirely as resulting from shared exposure and/or environment, because spouses in an outbred population typically do not share common genetics."[8] Similarly, researchers who focused exclusively on the 1918 influenza pandemic concluded that "the spouses of victims, often the only genetically unrelated member of the household, were paradoxically at the highest risk."[7]

When each influenza pandemic occurs, every incremental benefit is critical. Seemingly small steps can mean the difference between life and death.[46] Averaged across large populations, these steps almost surely result in fewer infections and deaths.

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