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Personal protective equipment in an influenza pandemic: a UK simulation exercise

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Summary There is limited experience of both operational and financial impacts that adoption of UK pandemic influenza infection control guidance will have on the use of personal protective equipment (PPE), patients and staff. We attempted to assess these issues from a live exercise in a hospital in north-west England. During this 24 h exercise, all staff on an acute general medical ward wore PPE and adopted the procedures described in the UK pandemic influenza infection control guidance. Teams of infection control nurses observed and recorded staff behaviour and practice throughout the exercise, including staff attitudes towards the use of PPE. Although World Health Organization recommendations on the likely use of high-level PPE (FFP3 respirators) proved to be excessive, more gloves and surgical masks were used than expected. Despite pre-exercise training, many staff lacked confidence in using PPE and following infection control measures. They found PPE uncomfortable, with even basic tasks taking longer than usual. Large quantities of clinical waste were generated: an additional 12 bags (570 L) per day. The estimates of PPE usage within this exercise challenge assumptions that large amounts of high-level PPE are required, with significant implications for healthcare budgets. A programme of ongoing infection control education is needed. Healthcare in a pandemic situation is not simply a case of applying pandemic influenza infection

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control guidance to current practice; hospitals need to consider changing the way care and services are delivered.

Introduction

During an influenza pandemic, healthcare staff delivering patient care may be at increased risk of infection through occupational exposure, although direct evidence for this is lacking. Appropriate infection control measures are required to reduce the risk of healthcare-associated spread of infection. In October 2005, the Department of Health, England and the Health Protection Agency issued infection control guidance to the National Health Service in preparation for an influenza pandemic.[1] These measures relate to hospital and primary care settings and include healthcare facility configuration and administrative controls to effect triage, isolation and cohorted care. The guidance also includes infection control principles and precautions such as hand hygiene and use of personal protective equipment (PPE) when working with patients assumed to have influenza.

Many of the measures outlined involve major changes to the way care is currently delivered and the use of infection control measures and PPE on a scale far beyond that experienced in the recent past. Few currently employed healthcare workers have experience of a pandemic and the lack of detailed operational data makes implementation of the current guidance challenging. Uncertainty is most evident in relation to procurement and supply. The current 'just in time' supply strategy, with minimal reserves, would be unsustainable during a pandemic; and consumables, most notably PPE, need stockpiling well in advance. If PPE stockpiles are to be based on more than simple guesswork, with serious implications for the safe delivery of healthcare on one hand, and financial wastage on the other, robust operational assumptions are needed. At the time we were unaware of any studies which attempted to address this question.

We therefore carried out a real-time pandemic simulation exercise on a typical general medical ward to identify operational issues and to quantify PPE usage around the provision of cohorted care to influenza patients in accordance with current UK guidance.

Methods

Wirral University Teaching Hospital NHS Foundation Trust identified an acute medical ward on its campus with a predominantly respiratory and gastrointestinal case-mix, receiving mainly acute and some elective admissions. Although not wholly designated for respiratory patients, the ward is typical of the sort that might be designated to provide cohorted care to influenza patients during a pandemic. The ward comprised 29 beds, arranged in three six-bedded bays, two four-bedded bays and three side rooms, two of which were supplied with negative pressure ventilation. The total complement of nursing staff comprised 14 trained nurses, five healthcare assistants and four domestic staff. Three of the trained nurses were male, the rest female. Four consultants have 'allocated' beds on the ward (two respiratory physicians and two gastroenterologists).

For the exercise, the ward simulated operating at the height of a pandemic, i.e. providing cohorted care for patients with influenza and influenza-like illness. All staff working or visiting the ward were required to wear PPE in accordance with national guidance (Table I) and the amount of PPE used was recorded hourly. Staff were excused participation where unmasked face-to-face contact was considered best practice for compassionate reasons, e.g. counselling for terminal cancer. In such situations, the PPE that should theoretically have been used, was recorded. The ward stock control system was used to quantify the usual use of PPE for comparison purposes, and the domestic supervisor provided information on the amount of clinical waste that would usually be generated over a 24 h period. The exercise ran for 24 h from 11:00 to allow time for staff briefings, ward preparation and a 'hot' debrief at the end. Patients and their visitors were not included in the exercise.

The proposal was discussed with the Chair of the hospital research ethics committee who was satisfied that the exercise did not fall within the remit of the committee. Key managers and clinicians were involved in planning meetings and all staff within the hospital were made aware of the exercise. Patients and their visitors were given written information about the purpose of the exercise and an opportunity

Table I Department of Health, England guidance for personal protective equipment for care of patients with pandemic influenza

	Entry to cohorted area but no patient contact	Close patient contact (within 1 m)	Aerosol-generating procedures[a]
Hand hygiene	✓	✓	✓
Gloves	×[b]	✓[c]	✓
Plastic apron	×[b]	✓	×
Gown	×	×[d,e]	✓[e]
Surgical mask	✓[f]	✓	×
FFP3 respirator	×	×	✓
Eye protection	×	Risk assessment	✓

[a] Wherever possible, aerosol-generating procedures should be performed in side rooms or other closed single-patient areas with minimal staff present.
[b] Gloves and apron should be worn during certain cleaning procedures.
[c] Gloves should be worn in accordance with standard infection control principles. If glove supplies become limited or pressurised, this recommendation may need to be relaxed. Glove use should be prioritised for contact with blood and body fluids, invasive procedures, and contact with sterile sites.
[d] Consider in place of apron if extensive soiling of clothing or contact of skin with blood and other body fluids is anticipated (for example, during intubation or caring for babies).
[e] If non-fluid repellent gowns are used a plastic apron should be worn underneath.
[f] Surgical masks (fluid-repellent) are recommended for use at all times in cohorted areas for practical purposes. If mask supplies become limited or pressurised, then in cohorted areas usage should be limited to close contact with a symptomatic patient (within 1 m).

to discuss it with staff beforehand. In addition, a member of staff was at the ward entrance throughout the exercise to give information. In the two weeks preceding the exercise, the hospital infection control team gave ward staff briefings on pandemic influenza, infection control procedures to be adopted, and how to don and remove PPE, including fit-testing of FFP3 respirators.

During the exercise, 17 infection control nurses (ICNs) from hospital and community-based settings acted as observers to monitor staff compliance with infection control guidance, give clarification and advice where appropriate and record significant issues relating to infection control procedures. The member of staff positioned at the ward entrance recorded staff movements in and out of the ward and purpose of visit. Patient visitors were not included in this census.

All ward-based staff involved in the exercise were encouraged to complete a self-administered questionnaire at the end of their shift to gather views on PPE comfort and its impact on the performance of their duties.

Kimberley Clark surgical masks and valved Kimberley Clark FFP3 respirators were used during the exercise. Disposable fluid repellent gowns were used where indicated.

Results

The exercise started at 11:00, 1 November 2006 and finished exactly 24 h later. Bed occupancy was 100% during this period and no unusual or untoward event occurred to affect the functioning of the ward or the running of the exercise.

The ward nursing and care staff worked their usual duty roster; an early shift 07:30 to 15:30, a late shift 15:30 to 21:30, and a night shift 21:00 to 07:45. The number of nursing staff working each shift is shown in Table II. It is important to note that in order not to compromise patient safety or care, additional staff were rostered; one extra healthcare assistant (HCA) and registered general nurse (RGN) from 11:30 until 13:30, an additional RGN from 13:30 to 21:30 and an extra HCA on the night shift.

The amount of PPE used during the exercise is shown in Table III; these numbers represent total use during the exercise, without adjustment for normal 'background' use. Eighteen 48 L sacks of clinical waste were generated during the exercise period.

During the exercise, 167 'visits' were made by 115 different hospital personnel; some individuals made multiple visits. Table IV shows the visits to the ward by staff group.

Table II Numbers of staff working during the 24 h period of the exercise

Period	RGNs	HCAs	Domestic	Admin.
11:00—13:30	4	5	2	1
13:30—15:30	8	6	2	1
15:30—21:30	4	1	1	—
21:30—07:30	2	2	—	—
07:30—11:00	3	4	2	1

RGNs, registered nurses; HCAs, healthcare assistants.

Table III Personal protective equipment (PPE) used over the 24 h period of the exercise

Equipment	Units used	
Surgical masks	650[a]	13 boxes
Gloves		
Small (pairs)	350 pairs[a]	7 boxes
Medium (pairs)	600 pairs[a]	12 boxes
Large (pairs)	250 pairs[a]	5 boxes
Disposable aprons	750[a]	5 rolls
Gowns	13	—
FFP3 respirators	13	<1 box
Eye goggles	13	—
Visor	1	—

[a] Rounded to the nearest 50.

Twenty-one ward staff (13 nurses, four HCAs, three domestics and one ward clerk) out of 23 (91%) completed the self-administered questionnaire. Of these, only one (5%) found wearing a surgical mask comfortable, six (29%) expressed no opinion, 12 (57%) found them uncomfortable and two (10%) found them very uncomfortable. Seventeen staff (81%) said that duties took longer, one unforeseen problem being extra time taken up for more frequent emptying of clinical waste bins. Nine (43%) felt that communication, such as answering the phone or talking with colleagues and patients, was more difficult. Three (14%) staff indicated to observers that mask wearing seemed to affect their hearing — almost certainly highlighting the importance of non-verbal and facial cues in everyday communication. One prominent operational need was for a 'holding area' where staff could don and remove PPE, perform hand hygiene and take a rest break outside of the cohort area.

At least three ICNs were present to observe practice throughout the simulation period. Overall, they found a good degree of adherence to general infection control precautions. However, particular aspects of the pandemic influenza guidance caused some uncertainty or concern among staff. These are detailed in Table V.

Discussion

In the UK, the number of single occupancy hospital rooms is relatively small compared with many health systems. Most inpatients are managed on wards, in open bays containing four to six beds. Consequently, UK pandemic infection control guidance is primarily based around the concept of cohorted care in designated influenza zones. PPE use by healthcare workers is based on standard principles and droplet precautions and applies to most contact situations.[2,3] High-level respiratory precautions are reserved for aerosol-generating procedures, where FFP3 respirators, closely equivalent to the US N99 classification, are used for respiratory protection.[4]

There are weaknesses and limitations in the study. A mainly respiratory medical ward was chosen to provide the nearest case-mix to a pandemic situation, and the exercise took place in November, when seasonal respiratory viruses are circulating. Notwithstanding, all simulations of this type are limited in that they do not take place during a pandemic period when respiratory illness will be ubiquitous and staff concerns and awareness heightened; this might alter (increase) compliance and consumption of PPE. The methodology employed involved a simple 'before and after' comparison. An alternative approach would have been a parallel-ward, crossover design study, to provide comparison with a control group where national guidelines were not implemented. This would, however, have increased the cost and complexity of the study. Units wishing to perform similar simulations might consider such an approach. For practical reasons the simulation only ran over 24 h; it is worth reflecting that during a pandemic, PPE use might decline over time as staff become either more proficient in its use, or compliance decreases. Conversely, if the pandemic virus were to be particularly virulent then compliance and use might increase. The presence of ICNs to monitor compliance and identify common issues was an important aspect of this simulation exercise and, although they did not intervene, their presence may have increased PPE consumption through a Hawthorne effect.

The simulation successfully highlighted issues associated with the implementation of national guidance and quantified the associated use of PPE in a typical UK hospital setting. In the worst-case scenario during the height of a pandemic, a cohorted ward could expect to use up to 5250 aprons per week compared to normal use of 400; 8400 pairs of gloves compared to 850; 4550 surgical masks compared to <10; and 90–100 FFP3 respirators and fluid-repellent gowns, none of which are commonly used on wards. With regard to aprons, gloves and surgical masks, there would be increases in use of up to 13-, 10- and 450-fold, respectively. This has significant implications not only for cost and procurement but also for storage; accommodating supplies on the ward for the 24 h of the exercise was difficult.

The few occasions ($N = 13$) when high-level PPE, and hence FFP3 respirators, was required was significantly lower than predicted. Five hundred FFP3 respirators were ordered for the exercise, reflecting a probably widely held perception that large amounts of high-level PPE may be needed. Since

Table IV Ward traffic over the 24 h period

Staff group[a]	No. of visits	No. of individuals	Reasons for visits	Comments
Medical staff	38[b]	20	Examining and assessing patients	1–6 visits per doctor; four doctors accounted for 18 visits (47%)
Nursing staff	32	17	Assessing and treating patients; accessing office accommodation	19 visits, involving 13 individuals were patient-related. One nurse made five visits (26% of total) to one patient. 13 visits were from four staff whose office is on the ward.
Porters	19	15	Transferring patients; delivering drugs, linen etc.	
Security staff	12	9	One patient needed 'specialling'	
Catering staff	9	6	Serving meals; collecting menus; dealing with special dietary requests	One assistant came on and off the ward four times during supper
Physiotherapists	8	3	Assessing and managing patients	
Healthcare assistants	8	8	Transferring patients; delivering medicines; getting charts signed	
Domestic staff	5	4	Delivering linen, curtains, etc.	
Pharmacists	3	2	Checking drug supplies	Drugs are checked every morning and afternoon
Radiographers	2	2	One patient required a portable chest X-ray	Two staff required per patient
Others	31	29	Routine tasks such as collecting and delivering paperwork, equipment, X-rays; taking blood	
Total	167	115		

[a] Staff based on the ward are not included in these numbers.
[b] No formal ward rounds were carried out during the exercise so this value is likely to underestimate the number of visits by medical staff.

the study was carried out, updated guidance relating to aerosol-generating procedures from WHO may further reduce the amount of high-level PPE required.[5]

The results of this exercise have significant financial and logistic implications as the FFP3 respirators cost £37.65 for 20 compared to £3.11 for 50 surgical masks: a 30-fold difference in unit price. In addition, FFP3 masks have a limited shelf-life (three years) unlike surgical masks, which have no expiry date.

Table VI compares the amount of PPE for a 29-bedded ward based on WHO guidance with the usage identified by our exercise.[5] There are striking differences between the two amounts: WHO guidance overestimates the use of high-level specialist PPE and underestimates the amount of basic PPE required. This focus on high-level PPE is further perpetuated in the recent publication by Swaminathan *et al*.[6] Once the pandemic virus is established and ubiquitous in the community, use of high level PPE will be unsustainable and impracticable. Both Swaminathan *et al*. and WHO highlight the dangers of extrapolating use based on generic assumptions and approaches to infection control and the need to tailor supplies of PPE to national infection control policies.

Another unexpected finding was the increased amount of waste generated by using the recommended PPE. Normally, the ward produces between four and six bags of waste over a 24 h

Table V Staff concerns/comments relating to personal protective equipment (PPE) and infection control

Aspects of infection control causing uncertainty or concern among staff
Donning and removal of PPE
Patients kept waiting (e.g. to be taken to and from bathroom) while staff put on PPE
Length of time for which surgical masks should be worn
PPE requirements for patients and patient environment contact (e.g. replacing a jug of water at patient's bedside; serving meals)
PPE requirements for waste disposal, and when and where to replace PPE
Wearing and removing PPE safely, e.g. not touching front of masks; not removing by pulling at the front but by untying from the back (wall mirrors are useful for staff to ensure that their masks fit properly)
Decontamination of ward equipment (e.g. telephones, door handles) and mobile equipment (e.g. trolleys)
Decontamination of ward environment
Decontamination of patient equipment (e.g. stethoscopes)
Hand hygiene after contact with inanimate objects (e.g. furniture, curtains)
General environmental cleaning with regards to frequency and extent
Precautions when nebulisers are used in a cohorted area
Contamination of paperwork in cohorted area (e.g. patient notes, menus)
Inadequate provision of hand-washing facilities in some areas (note: alcohol gel available at point-of-care as per the CleanYourHandsCampaign!)
Excessive use of alcohol hand rub instead of hand washing
Masks hampered communication; staff identities confused because aprons covered name badges
Concerns about potential anxiety and distress for patients through not being able to see the face of person treating them
Staff did not seem to take breaks because they were wearing PPE and became thirsty

period but during the exercise this rose to 18 bags, representing at least a 3-fold increase.

Infection control teams wishing to assess the effect of their educational activity and adequacy of their training are encouraged to use robust validated end-points. This was not done during this simulation. Observers and participating staff were, however, encouraged to record their perceptions and experiences in order to inform future staff training. Overall, observers felt that while staff had a good grasp of basic infection control precautions they were unsure about the additional measures recommended in the pandemic situation, despite training in the two weeks preceding the exercise. Uncertainty was also evident in participating staff as ICN observers occasionally gave conflicting advice, suggesting that interpretation of the guidance by specialists was not uniform. One-off infection control training is unlikely to be sufficient, and, during WHO Phases 4 and 5, more sustained efforts will be needed to ensure that staff are adequately trained.

Table VI Comparison of personal protective equipment estimates from the Arrowe Park Exercise and World Health Organization (WHO) guidance over seven days and based on 29 patients

	Surgical masks	FFP3 respirators	Gloves (pairs)
Arrowe Park simulation	4550	91	8400
WHO estimates	2436	406	406

At least 115 different staff made 167 visits to the ward related either to the provision of services (e.g. drug deliveries, linen and phlebotomy services) or providing direct care to patients (e.g. physiotherapy and radiology). This level of traffic would be highly undesirable during a pandemic, and as a consequence of the exercise, operational assumptions and plans are to be reappraised in order to minimise unnecessary staff movement. There also needs to be rigidity over allocating staff to work either in 'flu areas' or 'non-flu' areas of the hospital, and restricting movement between the two as far as possible.

An unanticipated observation was that many tasks and routine procedures took much longer than usual, despite the rostering of additional staff; this was particularly obvious at night when the drug round took twice as long as usual to complete. This exercise could be considered the worst case scenario, although it is possible that, as staff become more used to working in a pandemic environment, efficiency will improve. However, it also suggests that working practices may have to change to include cohorting patients requiring high levels of PPE and using a task-orientated approach to the provision of care.

National guidance recommends that staff wear a surgical mask in a cohorted area irrespective of close patient contact. The guidance acknowledges

that this is only strictly necessary for close contact (within 1 m) but the advice exists for pragmatic and practical reasons. Therefore masks may be worn for longer periods than might otherwise be the case. Most staff who responded to the questionnaire reported that PPE was uncomfortable and some felt that wearing a surgical mask interfered with communication. A few reported feeling hot and dry. Staff would therefore need to be encouraged to take frequent breaks during a pandemic despite tasks taking longer than usual.

In summary, many participants commented on the importance of addressing the subject and the usefulness of carrying out such an exercise. The results challenge the assumptions, both nationally and internationally, that large amounts of high level PPE (FFP3 respirators, gowns, eye shields, etc.) are required; the emphasis should be on adequate amounts of basic PPE. Staff felt the exercise had increased their confidence about dealing with an influenza pandemic if and when it occurs. The use of ICNs as observers throughout the simulation meant that behaviour and practice could be studied carefully. We believe that this is the first simulation of its kind in the UK, and that many hospitals would benefit from undertaking similar exercises in order to gain confidence and understanding of their own operational needs.

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