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CLINICAL PAPER

Lack of compliance with basic infection control measures during cardiopulmonary resuscitation—Are we ready for another epidemic?☆

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Summary
Objective: Healthcare workers in the emergency department are particularly vulnerable to communicable disease. This study aimed to evaluate compliance with standard precautions by analysis of the incidence and systems sources of such contaminations and by quantifying the use of personal protective equipment.
Method: A prospective observational study from 1 November 2005 to 30 April 2006, using analysis of video segments. Videotapes were recorded in two rooms designed for cardiopulmonary resuscitation of out-of-hospital cardiac arrests, and compliance with basic infection control measures by all emergency department crews was monitored.
Results: A total of 44 consecutive performances of cardiopulmonary resuscitation were recorded for time-motion analysis. The percentages of staff wearing personal protective equipment were 90%, 50%, 20% and 75% for masks, eye protection, gowns and gloves, respectively.

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Compliance ranking scored doctors as high, trainees as moderate and nursing staff as low. Overall contamination rate was 16.9×10^{-2} events/person-min. The two leading systems sources for contamination were lack of specific task assignments among rescuers (44%) and inadequate preparation for procedures (42%).
Conclusions: Among healthcare workers in the emergency setting, the study disclosed suboptimal compliance with basic infection control measures, including use of personal protective equipment and avoiding contamination. By further time-motion analysis of resuscitation sessions, major systems sources and strategies for improvement could be identified.

Introduction

Emerging infectious diseases and biological threats in recent years have created new challenges for all healthcare workers (HCWs). Microbes transmitted by airborne, droplet or contact routes generate the greatest anxiety among HCWs. The combination of patients with unknown communicable diseases and suboptimal adherence to basic infection control measures can lead to a catastrophic outbreak, such as the epidemic of severe acute respiratory syndrome (SARS) in 2003.[1–3] During that outbreak, 1701 HCWs were infected worldwide, as many as 21% of the 8098 cumulative cases.[4] The rates were even higher in places such as Canada (43%) and Singapore (45%),where there were more SARS cases in healthcare settings than in the general community.

HCWs in the emergency department (ED) are particularly vulnerable to the threat of communicable diseases because of the clinical characteristics of the patient population served and the highly contagious nature of certain diseases.[5–9] Outbreaks occur easily among unprepared and overwhelmed staff confronting unknown pathogens.[2,9–11] Because HCWs in the ED are a potential bridge for communicable disease into the community,[1,9,10,12,13] the need to implement infection control measures during all contacts with patients cannot be over-emphasised.

Performance of resuscitation in an ED would require that at least contact and droplet precautions be included in the protocol. However, actual adherence to these measures has rarely been explored. The purpose of this study was to evaluate compliance with the use of personal protective equipment (PPE) and to analyse the frequency and systems sources of contamination events among HCWs during cardiopulmonary resuscitation (CPR) in the ED.

Materials and methods

Study design, population and setting

From 1 November 2005 to 30 April 2006, we conducted a prospective, observational study in the ED of National Taiwan University Hospital in Taipei, Taiwan. The hospital is a tertiary care facility serving a metropolitan area of 2.65 million. The annual ED census is about 100,000. HCWs included doctors (emergency physicians and rotating residents), nursing staff and trainees, i.e. medical students, nursing students and emergency medical technicians (EMTs), for educational purposes.

During the study period, the initial 15-min segments of CPR for persons in the resuscitation room with out-of-hospital cardiac arrest (OHCA) were recorded by digital cameras from two separate angles. Any resuscitation of adults with OHCA was eligible for recording. OHCA patients younger than 18 years or with cardiac arrest due to traumatic events were excluded. The study protocol was approved by the Institutional Review Board of the National Taiwan University Hospital.

The location of the two digital cameras and the spatial arrangement of equipment and personnel in the resuscitation room are shown in Figure 1. The areas in the resuscitation room were defined as either 'contaminated' or 'clean' zones. The grey-dotted area in the diagram, containing patient stretcher, defibrillator and ventilator connection, was defined as contaminated because apparatus in this area would be in direct contact with the patient during resuscitation. Equipment in this area was disinfected after each use according to the concept of standard precautions, because the patient might be a carrier of unrecognised contagious disease. The other area in the resuscitation room was defined as clean; disinfection was not carried out after each resuscitation effort. The area definition was predetermined by the infection control team in the ED and was included in infection control education for all HCWs in the ED.

Outcome definition and collection

Video segments of all resuscitations were retrieved from the digital recording system and reviewed in detail. The method of video recording and time-motion analysis had previously been applied to assess the quality of CPR in the ED and during ambulance transport by the same research team.[14,15] In the current study, this method was adopted to evaluate compliance with basic infection control measures during resuscitation. Videos were reviewed by the study physicians and registered nurses using a structured recording form designed by the principal investigators, focusing on implementation of standard precautionary measures by the emergency personnel and on the frequency and systems sources of every contamination event.

Use of PPEs was categorised as 'inadequate' if a rescuer did not don appropriate equipment before starting resuscitation or approaching a patient. A 'contamination' event was recorded if the rescuer touched a clean zone (e.g. the charts, trolleys or monitors) after he or she came in contact with the contaminated zone (i.e. the patient, used defibrillators or used intubation equipment) without changing gloves or washing hands.

Data were collected from each recorded video segment of resuscitation regarding the total number and level of rescuers and the frequency of inadequate PPE use, including

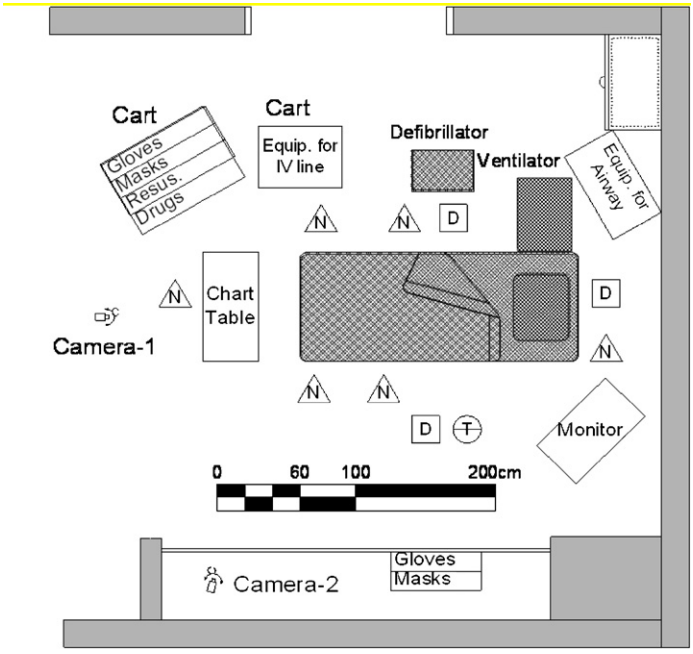

Figure 1 Locations of two digital cameras and spatial arrangement of equipment and personnel in the resuscitation room. *Notes*: 1. D: doctors; N: nurses; T: trainees. 2. Abbreviations: Resuscitation (Resus); Equipment (Equip); Intravenous (IV). 3. Grey-dotted areas were defined as 'contaminated'. Please see text for details.

masks, gowns, eye protection and gloves, among emergency workers. Video segments were also reviewed to evaluate contamination frequency and the systems and environmental sources leading to these events. Because all staff in the ED were at risk for contracting a contagious infectious disease,[10] HCWs of all levels participating in the resuscitation were examined and compared. The systems sources leading to contaminations were analysed by thorough detailed review of 10 randomly sampled videotaped CPR segments (using a random number table).

The potential sources of contamination were identified by the research team after review of some initial CPR video segments, and included chiefly lack of specific task assignment, inadequate preparation for the procedure, overcrowded space and individuals' carelessness. Four members of the research team, including two physicians and two registered nurses, were responsible for the main review of the sampled video segments. During the detailed review, when a contamination was shown on film the video was paused for discussion about the source of contamination. There were no categorisations without consensus among all reviewers.

Statistical analysis

Numerical data were shown by mean values and standard deviations (S.D.s) if in normal distribution, and by median values and quartiles if skewed. Categorical variables were recorded by counts and percentages. Relationships among binominal variables were analysed using chi-squared testing or Fisher's exact test, as appropriate. Poisson regression was applied to calculate the relative rates (RRs) and confidence intervals (CIs) for comparing contamination rates between doctors and nurses. A *p*-value less than 0.05 was considered significant. Data were entered and analysed using SAS software version 9.1 (SAS Institute, Cary, NC).

Results

Baselines

During the study period, a total of 44 consecutive adult, non-traumatic resuscitations were recorded for analysis. Demographic data of the patients and rescuers in the recorded CPR segments are shown in Table 1; 31 patients were men (70%) and the average age was (67 ± 17.7) years. The rate of return of spontaneous circulation was 25%. The average numbers of doctors (i.e. emergency physicians and rotating residents), nursing staff and trainees (i.e. medical and nursing students and paramedics) per CPR session were 3.7, 6.0 and 0.9, respectively.

Use of personal protective equipment

The overall rates for wearing PPE among all HCWs during CPR in the ED were 90% for masks, 50% for eye protection, 20% for gowns and 75% for gloves. The compliance with PPE use among different levels of HCWs is depicted in Figure 2. Compliance with wearing masks, eye protection and gowns differed significantly among doctors, nurses and trainees. There was no difference in the use of gloves.

Registered contaminations: incidence, locations and systems sources

A total of 687 contamination events were recorded in 44 consecutive CPR sessions, translating to an overall contam-

Table 1 Basic data from 44 episodes of cardiopulmonary resuscitation of persons with out-of-hospital cardiac arrest, video-recorded in the accident and emergency department

Patients	Number	Percentage
Men	31	70%
Women	13	30%
Age in years (mean ± S.D.)		67 ± 17.7
Initial rhythm		
Ventricular tachycardia or fibrillation	3	7%
Pulseless electrical activity	11	25%
Asystole	30	68%
Major comorbidity		
Hypertension	17	39%
Diabetes mellitus	9	20%
Malignancy	7	16%
Coronary artery disease	6	14%
Cerebrovascular accident	3	7%
Prehospital treatment		
Bystander cardiopulmonary resuscitation	6	14%
Defibrillation by automatic external defibrillator	3	7%
Advanced airway	10	23%
Intravenous route	10	23%
Radio alert by emergency medical system	17	39%
Return of spontaneous circulation	11	25%
Cause of out-of-hospital cardiac arrest		
Cardiac	12	27%
Non-cardiac	22	50%
Uncertain	10	23%
Rescuers (mean ± S.D.)		
Physicians		3.7 ± 1.8
Nurses		6 ± 1.7
Trainees		0.9 ± 1.6

S.D., standard deviation.

ination rate of 16.9×10^{-2} events/person-min. Among all clean zones, trolleys used to stock intravenous lines and medications were the most frequently contaminated sites. Nursing staff were more likely to commit contamination errors than physicians. The contamination rates for nurses versus doctors and the RRs and 95% CIs are shown in Table 2.

In the sampled videotaped CPR segments, 148 contamination events were observed and included in the detailed review of systems sources which were categorised as illustrated in Figure 3. There were two leading systems sources of contamination. The most common was lack of specific task assignment among rescuers (44%), i.e. a staff member was assigned two or more tasks across the clean and contaminated zones during the resuscitation. For example, if a staff member performing chest compressions moved on to record on the chart or retrieve medications from the trolley, contamination was registered. The other common source was inadequate preparation for procedures (42%), indicating that equipment for a specific task was not prepared and assembled beforehand so that the staff had to move back and forth between the clean and contaminated zones. For example, if during a procedure of intravenous catheterisation the nurse forgot to prepare the alcohol swab and went back and forth between patients and trolleys, contamina-

Table 2 Contamination rates (events/person-min)

Staffs and sites	Chart	Trolley	Monitor	Others[a]
Nurse	1.56×10^{-2}	10.13×10^{-2}	1.15×10^{-2}	1.84×10^{-2}
Doctor	0.47×10^{-2}	0.94×10^{-2}	0.43×10^{-2}	0.39×10^{-2}
Relative rate	3.3*	10.7*	2.7*	4.7*
95% confidence interval	1.8—6.2	7.1—16.2	1.4—5.2	2.4—9.0

[a] Includes door or light switch, control panel of mechanical ventilator, additional instruments, e.g. ultrasound machine.
* p-Value < 0.01.

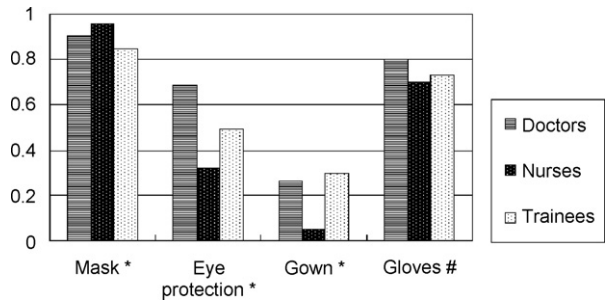

Figure 2 Compliance with personal protective equipments. *: p-value < 0.05; #: p-value = 0.382.

tion was registered. Further sources of contamination were classified as careless practice among HCWs (10%), for example leaving a patient's personal belongings on a trolley, or other causes (4%).

Discussion

There were three major findings of this study. First, although standard precautions have been promoted for two decades, compliance with PPE use remained unsatisfactory among HCWs during resuscitation. Second, contamination events occurred frequently among the rescuers, particularly among nursing staff. Third, time-motion analysis revealed the above two major systems sources leading to over 80% of contamination events. This was a first attempt to study compliance with PPE use and the frequency and systems sources of contamination in a working ED. In view of the disproportionate loss of HCWs during the SARS epidemic in 2003, the dismal performance we observed is very alarming.

Infection control techniques should be more stringently followed by HCWs in emergency healthcare settings, particularly when confronting potential epidemics of emerging infectious diseases, such as avian flu. In the 1980s, the CDC (Centers for Disease Control and Prevention, USA) published guidelines urging the use of 'universal precautions',[16–18] based on the findings that HCWs could not promptly identify most patients infected with contagious disease at initial presentation. Current concepts of infection control have evolved from universal precautions to detailed recommendations. 'Standard precautions' emphasise the potential mode and route of transmission, applying to all patients at all times; 'specific precautions' refer to patients with documented or suspected colonisation and infection with specific microorganisms.[19,20] Facing threats of tuberculosis, SARS, avian flu and other emerging infectious diseases, these recommendations remain valuable today. In fact, standard precautions involving use of simple PPE, including gloves, gowns, masks and eye protection, are effective in preventing serious contagious disease.[6,21] Lessons from the SARS epidemic indicated that poor compliance with the use of PPE,[2,21–23] and direct contact with a patient or an environment contaminated by respiratory droplets significantly increased the risk among HCWs of contracting SARS.[2,13,24,25]

Although there was compelling evidence that failure to implement appropriate barrier precautions is responsible for most nosocomial transmissions,[26] research that is focused on compliance with standard precautions is limited. Henry et al.[27] reported that standard precautions were not consistently used by ED personnel, who significantly overestimated their own compliance. Using bystander observations and a self-administered questionnaire, Henry found that gloves were the barrier device worn most frequently when appropriate (74%), followed by goggles (13%), gowns (12%) and masks (1%). In contrast, compliance with use of PPE was highest for masks (overall 90%) in our study. This is probably due to experience of the SARS outbreak. Caputo et al.[28] reported that HCWs' awareness of PPE use increased significantly during the SARS outbreak, but ebbed with time, agreeing with the unsatisfactory compliance noted in our observations. Use of PPE increased when the equipment was readily accessible to the rescuer. For example, gowns were used less often in our study because they were located outside the resuscitation room.

The ED has a high potential for propagating communicable disease through cross-contamination in a busy and crowded environment. During the SARS outbreak, Chen and colleagues[23] identified positive SARS coronavirus RNA in 9 of 119 samples from inanimate objects in the ED. Risk of transmission increased as more contamination events occurred. In the present study, rates of contamination (events/person-min) were higher among the nursing staff (10.13×10^{-2} for trolleys and 1.56×10^{-2} for charts). This meant that during a resuscitation session with five nurses for 20 min, approximately 10 contamination events occurred involving the trolleys and one to two involving the charts. Contamination events were recorded with greater frequency among nursing staff because of the character of their tasks and because they were responsible for executing and charting oral orders given by physicians during resuscitation.

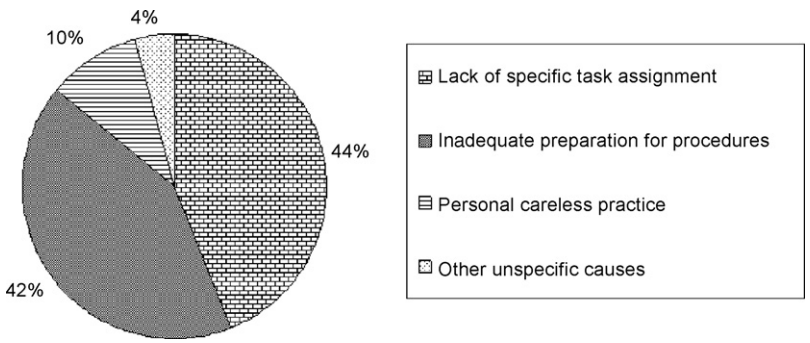

Figure 3 System sources of contamination.

In addition to personal awareness of standard precautions, a detailed analysis of the systems and environmental sources leading to contamination events is essential for formulating education and prevention strategies. In our study, over 80% of contamination events could have been avoided if two systems changes had been implemented, namely specific task assignment for rescuers and better preparation before performing invasive procedures. Other measures such as better spatial and personnel arrangement in the resuscitation room and clearer demarcation between clean and contaminated zones would also help reduce contamination.

There were some limitations to this study. First, the Hawthorne effect was inevitable in the video recording, time-motion analysis research. However, if the compliance was poor while under observation, it was probably worse at other times. Second, as there was no outbreak of transmissible disease, the direct biological effect of suboptimal PPE use and contamination could not be established. Although there is little evidence documenting disease transmission between rescuers and patients during resuscitation,[1,3,26,29] the high infection rates among HCWs during the SARS epidemic would suggest that this is significant. Adherence to standard precautions and avoidance of contamination during daily practice remain the best protection from the spread of contagious diseases.

Conclusion

This study disclosed suboptimal compliance with basic infection control measures, including using PPEs and avoidance of contamination events, among HCWs in an emergency setting. Through time-motion analysis of resuscitation sessions, major systems sources and strategies for improvement were identified. In view of the pivotal role of emergency services in combating emerging infectious diseases, information yielded by this study should be valuable in safeguarding against potential future outbreaks.

Conflict of interest

None.

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