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Isolation rooms for highly infectious diseases: an inventory of capabilities in European countries

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Summary Isolation of patients with highly infectious diseases (HIDs) in hospital rooms with adequate technical facilities is essential to reduce the risk of spreading disease. The European Network for Infectious Diseases (EUNID), a project co-funded by European Commission and involving 16 European Union member states, performed an inventory of high level isolation rooms (HIRs, hospital rooms with negative pressure and anteroom). In participating countries, HIRs are available in at least 211 hospitals, with at least 1789 hospital beds. The adequacy of this number is not known and will depend on prevailing circumstances. Sporadic HID cases can be managed in the available HIRs. HIRs could also have a role in the initial phases of an influenza pandemic. However, large outbreaks due to natural or to bioterrorist events will need management strategies involving healthcare facilities other than HIRs.

Introduction

In recent years, emerging and re-emerging infections, as well as the risk of bioterrorist events, have attracted increasing attention from healthcare authorities. The anthrax crisis in the USA during 2001, the severe acute respiratory syndrome (SARS) epidemic in 2003, the introduction of sporadic cases of viral haemorrhagic fever (VHF) in European countries, and the fear of an influenza pandemic due to an emerging human highly pathogenic strain, have highlighted that these threats pose a challenge to our public health systems.[1–3] These newly recognised problems have demonstrated the need for institutional and hospital preparedness, including the identification of healthcare facilities where patient care could be provided with appropriate standard of biosafety for other patients, healthcare workers and the whole community.

In recent years the European Commission has promoted and financed initiatives to improve preparedness and response to highly infectious diseases (HIDs) within member states. EUNID (European Network for Infectious Diseases, www.eunid.com) is a three-year project co-funded by the European Commission in 2003 and led by the Italian National Institute for Infectious Diseases 'L. Spallanzani', Rome. The main aim of EUNID is to promote co-operation and exchange of information among experts on preparedness and response to emerging or deliberately released agents causing HIDs.

EUNID representatives belong to 16 member states of the European Union (Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, and the UK), and they work together with the Coordination Team based in Rome and with some co-opted experts. All participants of EUNID are respected as authorities within their fields, have broad and multidisciplinary experience in the management of HIDs and their participation has been approved by the relevant national authorities.

An HID has been defined by EUNID participants as 'a disease transmissible from person-to-person that causes life-threatening illness, and presents a serious hazard in health care settings and in the community, requiring specific control measures.' According to participants, the diseases/agents that meet the agreed definition are: VHFs (Marburg, Ebola, Crimean Congo haemorrhagic fever, Lassa, and South American haemorrhagic fever — Junin, Machupo, Sabia, and Guanarito viruses); SARS; extensively drug resistant *M. tuberculosis* (XDR-TB); emerging highly pathogenic strains of influenza virus; smallpox and other orthopox infections (e.g. monkeypox, but excluding vaccinia virus); and other emerging highly pathogenic

agents, including agents of deliberate release that meet the definition (e.g. pneumonic plague).

Among various measures recommended to control HIDs, care of patients in an adequate hospital environment is essential in order to limit the spread of the diseases in the hospital setting and in the community. In order to achieve these goals, different technical approaches have been adopted worldwide. In the USA, three high level isolation units (HLIUs) are available. In general, these units are clinical facilities specifically designed to minimise the risk of nosocomial spread of HIDs, adopting engineering and safety measures usually used in biosafety level (BSL) 3 and 4 containment laboratories, that include negative air pressure ventilation for entire units, restricted access, special treatment of waste and other infrastructure and administrative controls not typically found in routine clinical settings. In the USA these units are usually constructed in connection with BSL 3—4 laboratories, in order to deal also with potential laboratory-acquired infections due to accidental exposure.[4,5] During the SARS epidemic, some countries that experienced local transmission managed the need for isolation by the creation of temporary isolation wards.[6] In Europe, different approaches exist. In some countries, HLIUs are available, or are in construction. In the UK, 'Trexler Units', a particular type of negative-pressure plastic isolator containing one or two beds, are in use.[7] In other countries, healthcare facilities specifically developed for the management of HIDs do not exist, and these patients are managed in negative-pressure isolation rooms.

According to EUNID, a high level isolation room (HIR) has been defined as a hospital room provided with negative pressure, with at least six air changes per hour, and an anteroom. We adopted this definition because it accords with international guidelines, and we believed that these features are crucial for effective patient isolation and may represent the minimum requirements for such facilities.[4,8—13] Negative pressure is essential for the isolation of patients affected by confirmed or suspected diseases with obligate, preferential or opportunistic airborne transmission (XDR-TB, SARS, human-adapted highly pathogenic strains of influenza virus, smallpox). The presence of an anteroom increases the efficiency of the system, providing an obstacle against pressure loss and reducing the risk of movement of contaminated air into common areas; moreover the anteroom provides a controlled environment in which donning and removal of personal protective equipment and other infection control procedures can be done safely.

In the present paper we describe the results of an analysis of current availability of HIRs for the isolation of patients with HIDs in Europe.

Methods

National public health authorities in all European countries were contacted by the EUNID Coordination Team, with the help of the European Commission, in the planning stages of the project in 2003, and were asked to suggest (although not to formally endorse) experts in HID/HLIU management as national representatives.

In 2004, during the first year of project activity, a data collection form was drafted by the Coordination Team, reviewed by the co-opted experts and sent to all national representatives. The aim of the data collection form was primarily to provide a uniform and comprehensive tool for the assessment of hospital capabilities. The form was developed as a survey tool and was not intended to set mandatory requirements or to establish a national legal standard for preparedness. Survey forms were issued in September 2004.

The following features were investigated: number of hospitals equipped with HIRs, total number of hospital beds within such rooms, location of HIRs, number of air changes ($\geq$6 or $<$6 air changes per hour), route of exhausting of air, connection with a laboratory at BSL 3/4 and availability of intensive care capabilities.

The number of HIR hospital beds per million of population was calculated using the most recent census or estimates in the document 'Population in Europe 2007: first results', developed by Eurostat and on its website.

Responses to the data collection form were discussed, reviewed and updated during both the first and second annual meetings of the EUNID project (27—28 May 2005; Rome, Italy, and 7—8 April 2006; London, UK). Finally, the Coordination Team prepared this report, shared it with national representatives and subsequent revisions were made in response to participants' comments until the content was agreed by all.

Results

Data were obtained from all 16 countries involved in the EUNID project and reflected the position in mid-2006. Data were complete and accurate from 12 countries, where national health authorities performed a survey recently (e.g. in Greece, where a complete survey of these facilities was

performed in 2004, for the occasion of the Olympic Games in Athens), or where data furnished by EUNID partners had been confirmed by national authorities or official documents. Information from Belgium and France was complete but not detailed, because only data about number of hospitals and rooms are held centrally. Finally, in the opinion of national representatives, data from Spain and Portugal may be partial.

The results are summarised in Table I. At least 211 hospitals had HIRs, with at least 1789 hospital beds. In particular, six hospitals in three countries (Germany, Italy and UK) had 14 hospital beds in 'advanced' isolation units, with direct connection with BSL 3—4 laboratory area. The mean number of hospital beds in each country was 112, ranging from 0 in Austria to 726 in Italy, with a median of 67. The number of HIR hospital beds per million of population served is given in Table I, and ranged from 0 in Austria, to 31.5 in Luxembourg. The geographical distribution of HIRs is shown in Figure 1.

Thirteen countries were able to provide information on intensive care capability. The total number of beds in HIRs equipped with such capability was 342, mostly present in Italy (245 beds) and Denmark (40 beds) where this was provided by means of portable devices, as was the case in The Netherlands (four beds). The other 56 beds with intensive care capability, distributed in six countries, were mostly located in intensive care units. The mean number of hospital beds in HIRs equipped with intensive care capability in the 13 countries from which these data were available, was 26.3 (median: 4; range: 0 in Austria, Estonia, Ireland and Spain to 245 in Italy).

Data about the way that air was exhausted were available from 11 countries. In almost all countries, the air was exhausted to the outside through HEPA (high efficiency particulate air) filters; in two countries, air was exhausted directly to the outside, without HEPA filtration. Information about sealing of such rooms was obtained from nine countries. In all but two (Luxembourg and Portugal), HIRs were sealed.

The location of HIRs was explored, and these data were available from 13 countries. In four countries these rooms were located in a separate building or in a separate ward with a separate entrance; in four countries these rooms were located in the same ward as other rooms, mainly in infectious disease or intensive care wards. In five countries, both approaches were used.

Specific data about each country are available on the EUNID website (www.eunid.eu).

Discussion

The clinical care of patients with suspected or confirmed HIDs is a real challenge for healthcare facilities. Indeed, special strategies should be put in place with the aim of reducing the risk of transmission of these diseases. These strategies include the application of infection control procedures, including the isolation of patients in rooms with specific technical features.

For some of these diseases (VHFs, smallpox, XDR-TB) a clear need for such facilities exists. For others (such as SARS, influenza), less costly approaches that consider strict application of appropriate transmission-based isolation measures in conventional hospital rooms might be considered. However, the use of HIRs is also recommended by international guidelines and European legislation in these cases. Indeed, airborne transmission of SARS and influenza virus has been suggested in many instances, especially during aerosol-producing procedures in healthcare settings.[14—16] In a recent guideline from the World Health Organization, SARS and human infections caused by a new influenza virus are considered acute respiratory diseases that may constitute a public health emergency of international concern, and consequentially the use of an airborne precaution room is suggested.[8] Finally, according to European legislation, biological agents prone to cause public health emergencies should be managed in accordance with the precautionary principle, and engineering control measures should be implemented in order to avoid or minimise the release of biological agents into the workplace.[17]

Rooms with specific technical features for the isolation of patients are already in use in Europe. Since 2000, nine imported cases of human-to-human transmissible VHFs have been isolated and treated in western Europe.[18—20] During the SARS epidemic, 33 confirmed cases were imported into Europe, and mainly isolated in such rooms.[21] More recently, an Italian patient returning from Nepal with suspected VHF was isolated in a hospital provided with HIRs (unpublished data). No local transmission has occurred in Europe. Although, to date, no human cases of influenza A/H5N1 have been reported in European Union member countries, isolation rooms have also been used in the management of some potential cases in Belgium, Greece and The Netherlands.[22—24]

This inventory has some limitations. The data collected is not complete with only partial information from some countries. Furthermore, comprehensive data from the other countries has been difficult to obtain, except where a national

Table I Hospital provided with high isolation rooms (HIRs) and number of hospital beds in countries participating in the European Network for Infectious Diseases (EUNID) project

Countries		Hospital provided with HIR with ≥6 air changes per hour + direct connection with a BSL 3–4 lab area, and no. of beds within	Hospital provided with HIR with <6 air changes per hour + direct connection with a BSL 3–4 lab area, and no. of beds within	Hospital provided with HIR with ≥6 air changes per hour and no. of beds within	Hospital provided with HIR with <6 air changes per hour and no. of beds within	No. of HIR hospital beds with IC capabilities	No. of HIR hospital beds available per million population
Austria	Hospitals	0	0	0	0	0	0
	Beds	0	0	0	0		
Belgium	Hospitals	199 negative-pressure rooms in 27 hospitals, mostly with anteroom. Further data not available.					NA
	Beds						
Denmark	Hospitals	0	0	6	0	40 (portable devices)	14.3
	Beds	0	0	78	0		
Estonia	Hospitals	0	0	0	1	0	11.2
	Beds	0	0	0	15		
Finland	Hospitals	0	0	17	0	24	28.4
	Beds	0	0	150	0		
France	Hospitals	67 negative-pressure rooms in 17 hospitals. Further data not available.					NA
	Beds						
Germany	Hospitals	3	2	2	1	10	0.3
	Beds	10	4	6	4		
Greece	Hospitals	0	0	0	25	No data	6.0
	Beds	0	0	0	67		
Ireland	Hospitals	0	0	10	0	0	15.5
	Beds	0	0	67	0		
Italy	Hospitals	1	0	35	9	245 (portable devices)	12.3
	Beds	2	0	645	79		
Luxemburg	Hospitals	0	0	1	0	7	31.5
	Beds	0	0	15	0		
Portugal	Hospitals	0	0	5	0	6	2.7
	Beds	0	0	29	0		
Netherlands	Hospitals	0	0	1	0	4 (portable devices)	0.2
	Beds	0	0	4	0		
Spain	Hospitals	0	0	3	0	0	0.2
	Beds	0	0	8	0		
Sweden	Hospitals	0	1	1	28	3	25.9
	Beds	0	3 (2 if IC)	2 (1 if IC)	231		
UK	Hospitals	2	2	About 20	0	3	1.7
	Beds	2	2	About 100	0		

(*continued on next page*)

Table I (*continued*)

Countries		Hospital provided with HIR with ≥6 air changes per hour + direct connection with a BSL 3–4 lab area, and no. of beds within	Hospital provided with HIR with <6 air changes per hour + direct connection with a BSL 3–4 lab area, and no. of beds within	Hospital provided with HIR with ≥6 air changes per hour and no. of beds within	Hospital provided with HIR with <6 air changes per hour and no. of beds within	No. of HIR hospital beds with IC capabilities	No. of HIR hospital beds available per million population
Total[a]	Beds	14	9 (8 if IC)	1104 (Belgium and France not included)	396 (Belgium and France not included)	342 (289 with portable devices)	

NA, not applicable; IC, intensive care.
[a] Total number of hospitals cannot be calculated, because some hospitals have more types of rooms, and are reported on more than one column.

survey had been carried out recently by public health authorities, or where the data had been confirmed by national health authorities. Despite these limitations, we consider this inventory as nearly complete. Indeed, EUNID representatives are mainly physicians who lead, or work in, the main referral centre for the management of patients affected by suspected or known HIDs, and they are updated about the availability and the functioning of their own and other HIRs in their own country.

The number and the deployment of HIRs in each country reflects both geographical characteristics and differences in economic and political policies that exist in European Union member states. In some countries (Belgium, Finland, Greece, Ireland, Sweden) these rooms are widely disseminated across the whole country, and are usually represented by one or few rooms in general hospitals, usually attached to infectious diseases wards. In some others (Estonia, Germany, Luxembourg, The Netherlands, Portugal), the HIRs are located in one or few referral hospitals, each covering a part of the country. In Germany, HIRs are placed in specifically equipped, highly specialised facilities, located in a separate ward or building. By contrast, both approaches are used in Denmark, Italy and the UK. Indeed, few referral hospitals or units contain specifically equipped facilities, but other HIRs are also available in many hospitals. In particular, the large number of hospitals provided with HIRs in Italy is due to a national law that mandates the provision of at least one HIR in all infectious diseases wards, in order to comply with an increased number of HIV-positive patients with tuberculosis.[25]

The availability of HIR hospital beds per million population is greatest in Luxembourg, which is a very small country, Scandinavian countries (Finland, Sweden, Denmark) and Ireland; among the most populous countries, Italy has the greatest number of hospital beds per million inhabitants, while the UK, Germany and Spain have very few.

Among the technical features investigated, few differences were observed. Nine partners responded to the question about sealing of HIRs in their countries, and all but two stated that the rooms were sealed. Slight differences also existed in the details of air exhausting. Re-circulation of HEPA-filtered air was not used. Therefore, we can say that the engineering criteria used for HIRs are similar in the European countries monitored by the EUNID project.

The adequacy of the total number of hospital beds in HIRs in the European countries participating in EUNID will depend on the circumstances that

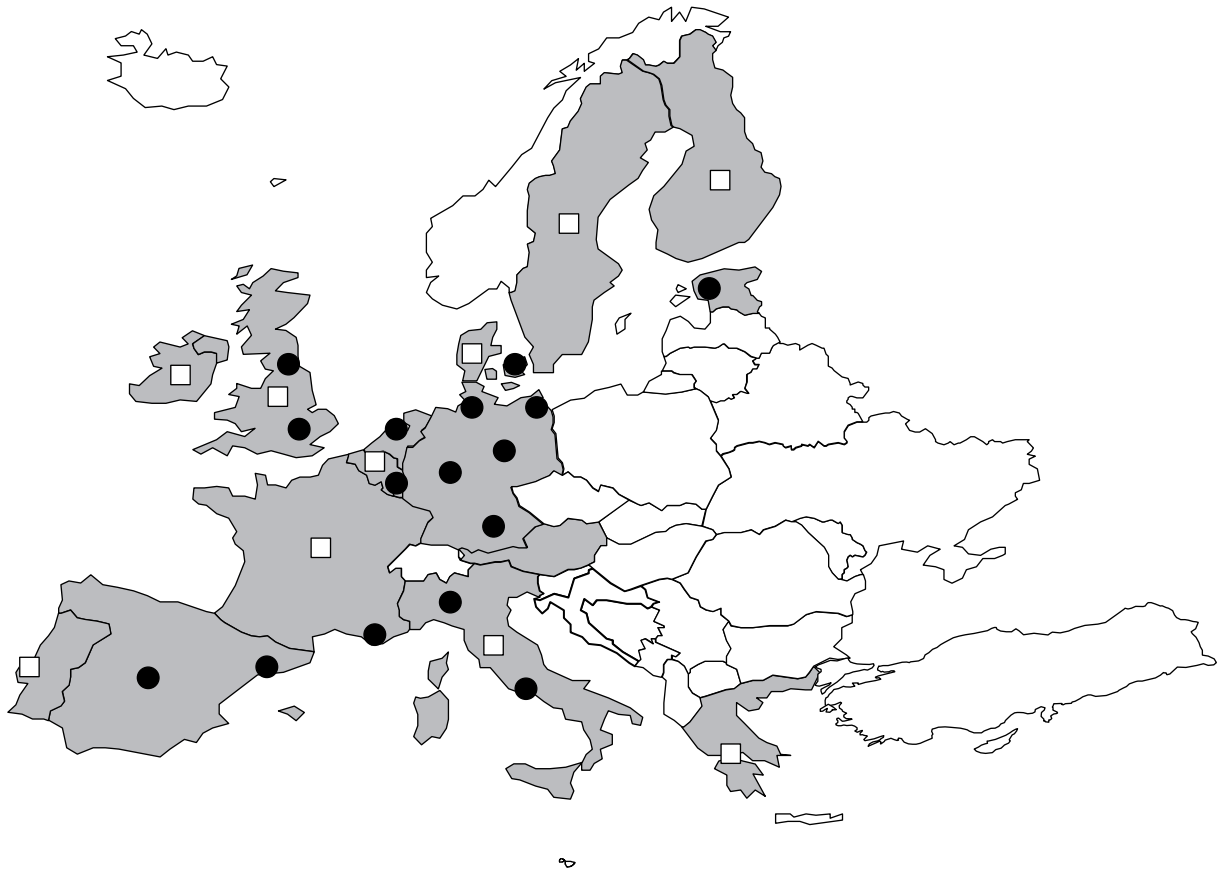

Figure 1 Geographical distribution of hospitals provided with high isolation rooms (HIRs) in countries participating in the European Network for Infectious Diseases (EUNID) project. Black circles: main hospital with HIRs; white squares: hospitals with HIRs widely distributed in the country.

might be faced. The sporadic introduction of few cases of HIDs in Europe can be managed easily in the currently available HIRs. Currently available HIRs could have a role also in the initial phases of an influenza pandemic, in order to isolate the first cases and to delay as much as possible the establishment of effective human-to-human transmission in the country.

Transnational collaboration among countries should be implemented whenever possible, because well-established relationships would be essential if the cases exceed the HIR capacity in a country or where transport across a state border was easier than across difficult terrain (such as mountainous areas), although the transport of these patients may represent a challenge. Indeed, arrangements for transport of HID patients to HLIUs in Europe vary, as do the legal regulations applicable in each country, as also evidenced by the compendium of national guidelines on HID developed by EUNID (available on website). Most countries require ambulance crews to be specially trained but not all require the use of special vehicles. In some countries, special ambulances with controlled and filtered ventilation are used; others use standard ambulances with the crew wearing various levels of personal protective equipment; and others use patient isolators to protect the crew and environment. Sweden, Germany, Italy and the UK have arrangements for, and experience of, national and/or international aeromedical transport for their citizens, both using ambulances transported on an airplane, or special air transport isolator.

The decision whether to move a patient with HIDs requires a number of considerations: the difficulty of continuing exceptional precautions for the time necessary for transport, the exhaustion of personnel caring for the patient, and the tendency for damage to personal protective equipment when working in confined spaces. Furthermore, if small isolators are used to transport patients, it is very unpleasant for the patient and very difficult to provide appropriate care for a sick patient in such a small space. Moreover, the time of transport should be carefully planned, taking into consideration geographical features of the route and meteorological conditions. A balance is

necessary between transport distance and feasibility, and the availability of HIRs.

Despite collaboration among member states, once person-to-person transmission of an HID is occurring within a community, e.g. large outbreaks due to a pandemic strain of influenza, or following deliberate release of bioterrorist agents, HIR-based care becomes less feasible, and there is the need for other approaches such as plans for surge capacity and for alternative care centres.

The total number of 342 hospital beds in HIRs equipped with intensive care capabilities is deceptive; the large majority is represented by the rooms present in Italian and Danish hospitals, where ventilation can be provided through portable devices. In the other 12 countries from which we have data, intensive care capabilities are not present in three countries and in the remaining eight countries 65 hospital beds in HIRs have intensive care facilities. The ability to provide intensive care is important not only for preparedness for major events, but also in the management of sporadic cases of HIDs. Indeed, the diseases defined as highly infectious are life-threatening infections that often require intensive care support.[19,26–28] In our opinion, this deficiency represents a risk to the hospital population and to the community, as patients may be moved to an ICU where isolation measures cannot be applied easily. The creation and maintainance of transnational agreements are other possible options, but the transport of highly infectious patients requiring intensive care from one country to another is usually not feasible.

It is important to remember that the availability of rooms provided with acceptable technical features is not sufficient for the safe handling of patients with HIDs. Indeed, the adequacy of logistic issues, as well as the existence of specific infection control procedures, is essential. A comprehensive analysis of adequate specifications for HLIUs has been developed both by a panel of experts in the USA and by members of EUNID project.[4,29] Moreover, specific recommendations on special medical procedures to be performed on these patients have been developed.[30]

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Conflict of interest statement
None declared.

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