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REVIEW ARTICLE

Is Your Interventional Radiology Service Ready for SARS?: The Singapore Experience

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Abstract

The recent epidemic of severe acute respiratory syndrome caught many by surprise. Hitherto, infection control has not been in the forefront of radiological practice. Many interventional radiology (IR) services are therefore not equipped to deal with such a disease. In this review, we share our experience from the interventional radiologist's perspective, report on the acute measures instituted within our departments and explore the long-term effects of such a disease on the practice of IR.

Key words: Severe acute respiratory syndrome—Interventional radiology—Infection control

Aseptic techniques have traditionally been practiced in diagnostic and interventional procedures for the purpose of reducing the risk of local and systemic infections in the patient. With the emergence of blood-borne pathogens, notably human immunodeficiency virus and hepatitis B and C viruses, the use of universal precautions for all health care workers (HCW) whenever they may be exposed to a patient's blood or other body fluids were recommended [1, 2]. These measures have been generally embraced by all, including interventional radiologists, who under the auspices of the Society of Cardiovascular and Interventional Radiology (now known as Society of Interventional Radiology), issued its own set of guidelines in 1997 [3].

The response to nosocomial transmission of an airborne disease like tuberculosis has, however been more muted [4]. Therefore, when severe acute respiratory syndrome (SARS) swept through many parts of East Asia during the first quarter of 2003, many radiologists were woefully prepared for such an encounter.

Our experience from the interventional radiologist's perspective, the lessons learned and issues raised in our fight against SARS, are crystallized in this paper. It is our hope that this report will prompt our readers to plan and prepare their radiology service for an outbreak of an infectious disease such as SARS. In so doing, may your response to the question "Is your interventional radiology (IR) service ready for SARS?" be "A Success Story."

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SARS in Singapore

In the 2nd century AD Galen noted that when many sicken and die at once, one should consider the air that we breathe. This Dr. Carlo Urbani did, which culminated in the World Health Organization (WHO) issuing an unprecedented worldwide alert regarding an outbreak of atypical pneumonia in southern China, Hong Kong and Vietnam on March 14, 2003 [5].

Singapore was affected when 3 Singapore nationals returned to Singapore from Hong Kong on February 25, 2003. While in Hong Kong, these 3 individuals were exposed to an infected guest staying in their hotel [6]. Unfortunately, one of these 3 was highly infectious (a super-infector), which accounted for the rapid spread of infection to 2 hospitals and threatened the community. In the period between March 1, 2003 and May 31, 2003 when Singapore was declared SARS-free by WHO, there was a total of 206 infections of which 84 involved HCW. Thirty-one deaths were recorded and 9 patients remained in the hospital [7].

Acute Phase Measures Instituted for IR

In many institutions, the interventional/angiography suite is located within the radiology department. Measures instituted for the rest of the radiology department in response to an acute outbreak of an infectious disease [8, 9] are therefore also applicable to the IR service. In this section, we would instead like to emphasize measures and issues that are more germane to the practice of IR.

Decentralization of Services

Over the past several decades, administration in radiology has focussed on efficiency and bottom lines. Consequently, resources were centralized to maximize staff and patient throughput. With the advent of SARS, there is a need for decentralization of services and segregation of patients according to risk for nosocomial transmission of infection. As far as possible, procedures on SARS suspects should be performed at a designated isolation facility, preferably outside the main radiology department. Keeping possibly infectious patients out of the main radiology department will reduce the risk of transmission to attending staff, other patients or unsuspecting visitors of the department. Of the 206 cases of SARS in Singapore, 10 were radiology-related infections. Four involved staff members and the 6 remaining were either visitors or outpatients of the department. The segregation of patients with SARS to dedicated isolation facilities will also allow the main radiology department to continue providing services to other non-infected patients, restoring some semblance of efficiency.

It is, however, unlikely that most IR services would have the luxury of physically separate outpatient, inpatient and isolation facilities. Under such circumstances, the solution may be to explore temporal segregation of services to different groups of patients. It is also possible to take advantage of resources outside the department, namely, endoscopy, cardiology or even operating theaters, supplemented with portable fluoroscopic units, some of which have digital subtraction capability.

Portable if Possible

To minimize movement of infected patients and its attendant risk of nosocomial transmission of infection, interventional procedures for SARS patients should, if possible, be performed on a "portable" basis at the patient's bedside in his isolation room. This will naturally mean the procedures will be limited to ultrasound-guided interventions. It is fortuitous that US has become the modality of choice for image guidance in an increasing range of interventions [10].

The ultrasound machine is completely protected with clear transparent plastic or Cling Wrap (Cartigny Pty, NSW, Australia) before pushing the machine into the patient's room. The procedure can proceed as one would normally after covering the transducer with a sterile probe cover. The plastic covers are removed at the end of the procedure upon leaving the room and the machine is wiped down using chlorhexidine-ethanol wipes (Mediwipes, Tollyjolly, Singapore).

Vetting, Triage and Verification of Requests for Intervention

At no other time has it been more crucial to vet, triage and plan the case schedule. SARS has prompted us to adopt a more holistic approach to each patient and encouraged communication with our referring physicians. It is at this time that indications for the procedure are verified and a patient's infectious risk is stratified. Referral to an infectious disease physician is requested when there is doubt. This is especially pertinent so long as a reliable diagnostic tool kit is not available. Though no medically emergent procedure is denied, on occasion it may be necessary to delay non-urgent procedures until a patient's risk status is further elucidated. Knowing the patient's risk status will help determine the need for use of isolation facilities and also enable the appropriate level of infection control precautions to be employed.

Before a patient is called down for any procedure, it is imperative that all pre-procedure preparations have been completed. This will reduce unnecessary exposure resulting from aborted or cancelled procedures and minimize the amount of time patients spend in the department.

Adoption of Full Personal Protective Equipment (PPE)

At present, information concerning the transmission of SARS is incomplete. The transmission of SARS appears to occur predominantly by direct contact with infectious material, including dispersal of large respiratory droplets. There is, however, a possibility that SARS could spread through the airborne route. In its interim guidelines, the Center for Disease Control and Prevention (CDC) of the United States has recommended the use of PPE appropriate for standard, contact and airborne precautions [11]. These comprise hand hygiene, gloves, gown, caps, shoe covers, eye protection and qualitative fit-tested N95 respirators. The use of Powered Air Purifying Respirators (PAPR) in aerosol-generating procedures was also highlighted and will be discussed in greater detail in the following section.

Adoption of these infection control measures means frequent hand washing. A change of gowns, caps, gloves and shoe covers is enforced between patients; the N95 mask is also changed daily or after treating infected patients. These measures may add to the complexity and duration of doing a procedure. Fortunately, this is only in the initial period, as most individuals were able to adapt and improve with time, practice and familiarity. There should be no need for sterility to be compromised as a result of donning PPE.

Pre-Procedure Preparation of Room

All nonessential and mobile equipment is moved out of the procedure room to avoid possible contamination. Immobile or essential equipment within the procedure suite is covered with disposable plastic covers or paper drapes to decrease the amount of cleaning subsequently required (Fig. 1). Surfaces that are difficult to disinfect, such as switches and control panels, should also be covered by plastic that is either discarded or disinfected between patients. Non-disposable linen should preferably not be used. Clean and contaminated

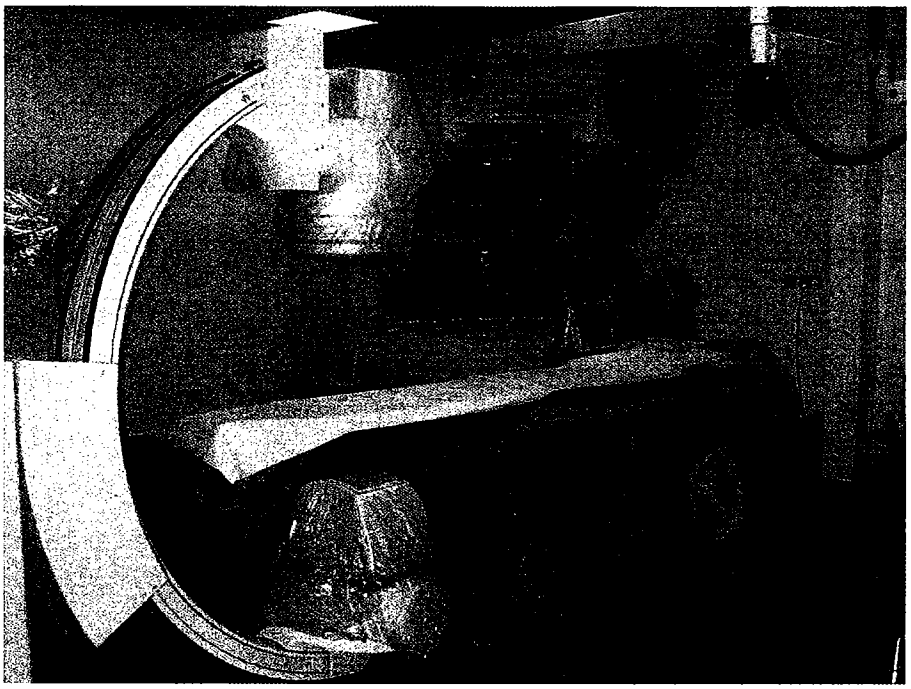

Figure 1. Angiographic suite prepared to receive a patient suspected of SARS. All nonessential equipment has been removed. Image intensifier and TV monitors are covered with disposable plastic covers. Angiographic table is covered with paper drapes.

work areas are to be clearly demarcated to contain contaminated objects and subjects within the designated area and facilitate subsequent clean up.

Post-Procedure Clean Up

This is a mundane but critical component of infection control measures. Hitherto, scrub teams have always been meticulous when gowning up for a procedure (to maintain sterility) but more lax when degowning at the end. The SARS paradigm shift requires commensurate care to be exercised in removal of PPE, in order to avoid contamination of oneself or our colleagues. Proper disposal of soiled PPE and cleaning of used PAPR masks/hoods become every individual's responsibility. Access to the workstations in the reporting area and written post-procedure entry into the case notes by the radiologist are allowed only after removal of his PPE and proper hand washing. Strict personal discipline and peer audits are needed.

The radiographers are also accountable for the thorough cleaning up of imaging equipment, while nurses ensure proper disposal of instruments and supplies. Non-disposable instruments are soaked in antiseptic solution before decontamination and sterilization. Exposed surfaces including door handles, arm guards, TV monitors, console panels in the control room and keyboards are also wiped down with 70% ethanol or chlorhexidine-ethanol wipes.

All disposable plastic coverings are changed in between patients. Biohazard and disposal bags are discarded based on a principle of single patient use. Floors are mopped with disinfectant (1:40 diluted bleach, sodium hypochlorite 1/1000 ppm) and rooms are ventilated for at least 30 min before bringing in the next patient. Vacuuming and mechanical buffing of floors were halted to reduce risk of aerosolization of potentially infectious material.

Education, Training, Protocols and Audit

These provide the foundation for effective infection control measures. All ranks of staff from the radiologist down to the porter and cleaner need to be included in the education program.

Rigorous training, especially crucial in the initial phase of implementation, serves to ingrain these measures in individuals. Written list of protocols put up in each room provide an undisputed reference. A regular audit of staff on careful hand hygiene, wearing of N95 respirators and strict adherence to infection control procedures will ensure continued compliance. Mutual checks on one another will ensure that no one enters the angiography suite without donning the appropriate barrier protection.

Review of Resuscitation Protocols

Arising from a high likelihood of aerosolization during resuscitative measures, changes were implemented in our resuscitation protocols. In our institutions, PAPR was recommended for the physician performing intubation, if not for the entire resuscitation team. PPE must also be donned before commencing resuscitation, even at the expense of prolonging the time to initial resuscitation. This was a par-

adigm shift from pre-SARS days when a quick response seemed to be all that mattered.

Radiation Protection Versus Infection Control

In many institutions it is a common practice for staff to step out or seek shelter in the control room of the angiography suite during image acquisitions to limit radiation exposure. However, in the face of a highly virulent disease such as SARS, it may be advisable to have staff stay inside the room behind lead screens to avoid cross-contamination of less adequately protected staff outside the intervention suite or in the control room. Of course, in line with radiation protection principles, one should maximize the inverse square law to their advantage to reduce radiation exposure.

When dealing with patients suspected of SARS, there should ideally be 2 separate teams: an operating team comprising a physician operator and an assistant. Another individual, usually a radiographer, with full PPE but non-sterile, could help with control of the angiographic table and any additional equipment requested by the operator. A support team comprising a radiographer technician and a nurse is stationed outside the procedure room to help with controls and monitoring of the patient's vital parameters. There will therefore be minimal movement in and out of the potentially contaminated room and this helps maintain clean and contaminated areas.

Ventilation

In planning for aortic stent grafting and other potentially more complex procedures, the modern angiography suite is constructed with an operating theater in mind. The ventilation in such rooms is therefore pressurized positively with vertical airflow and 10-15 air exchanges per hour. Air first passes over the patient and then to the staff. The rationale for such an arrangement is to reduce the likelihood of transmission from the operator to the patient. The converse is required when isolating patients suspected of airborne infections. Air is drawn into the room from the corridor, with air passing first over the staff and then the patient, limiting the exposure of staff to contaminated air. The conundrum that exists: do you protect the patient or the operator? We currently maintain positive pressure in the interventional suites, have HEPA (high efficiency particulate air) filtration of the air before venting it out and prescribe use of PAPR by the operators in high risk situations.

Using PAPR

PAPR is a positive pressure respirator system that protects against the inhalation of harmful materials. The device consists of a battery-driven blower, filters and a facemask or hood. The blower and filters are usually belt mounted and worn around the waist and the mask or hood is connected to the blower by a breathing hose (Fig. 2). Air is drawn through the filters by an electronically controlled fan in the blower before entering the breathing hose and mask/hood. Filtered air from the blower is generated at 120 liters per minute or more. The airflow is much higher than the wearer needs to breathe, and the excess flow creates a positive pressure as it passes through the mask. This pressure pushes air out, and keeps contagion from creeping in.

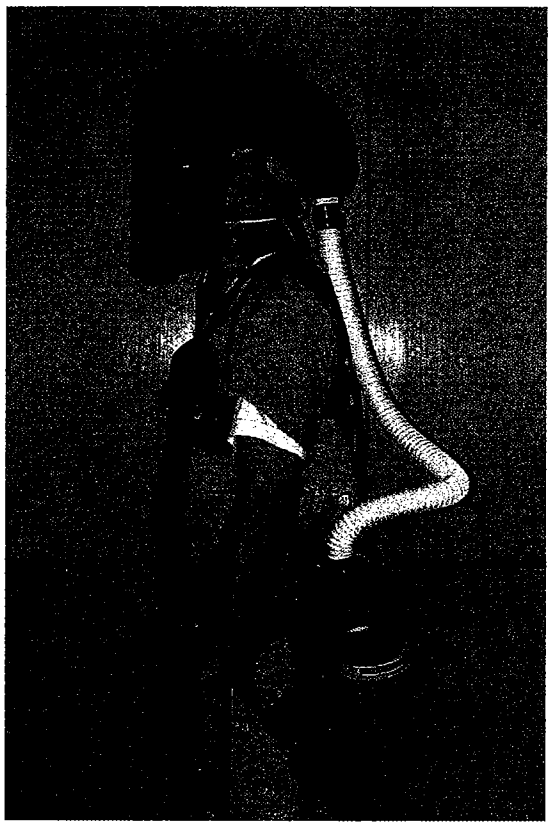

Figure 2. Radiologist with PAPR unit, before donning of sterile gown. Note that PAPR is worn outside the lead apron. This particular unit is equipped with a hood, covering the entire head. A N95 face mask is worn beneath the hood.

The choice of filters depends on the type of hazards (chemical, biological, radiological, nuclear agents) present. Although there are filters that protect against more than one hazard, there is at present no "all-in-one" filter that protects against all substances. In the context of SARS, particulate filters, namely, HEPA filters, with 99.97% filtering efficiency for particles 0.3 μm or larger, are used. A variety of face masks and hoods are available. The masks may be tight or loose fitting, cover the face partially (mouth and nose) or fully (mouth, nose and eyes). Hoods completely cover the head and neck, with some covering the shoulders and upper torso as well.

At present, there is inadequate information to determine the role of PAPR in protecting HCW from SARS. A questionnaire survey of hospital staff by Seto et al. [12] testifies to the adequacy of contact and droplet precautions, in which

Table 1. Indications for use of PAPR

1. Interventional procedures in all SARS and SARS-suspect patients.
2. Aerosol generating procedures including:
   a. insertion of naso-gastric or naso-jejunal feeding tubes
   b. percutaneous gastrostomy
   c. esophageal, gastric or duodenal dilatation and/or stenting
   d. tracheal dilatation and/or stenting
   e. lung or pleural biopsy
   f. bronchial arterial embolization (these patients could have heavy bouts of coughing due to hemoptysis)

no staff became infected when masks, gloves, handwashing and gowns were used. Although reassuring, the exclusion of aerosolization is a significant caveat. It is our practice to use PAPR when performing any procedures on SARS or SARS-suspect patients, in aerosol-generating procedures or if patients are expected to have significant respiratory symptoms (Table 1). It might seem excessive to extend the use of PAPR to include all patients subjected to aerosol-generating procedures. This latter recommendation is an extreme precautionary measure in response to transmission of SARS to HCW by patients in whom the typical manifestations of SARS were masked by the patient's underlying co-morbidities. The advent of a reliable diagnostic kit for SARS will certainly help refine these interim indications for PAPR.

Although it is not the manufacturer's recommendations, we don a N95 mask beneath the PAPR hood for several reasons. Firstly, PAPRs are shared amongst various HCW. Wearing an additional mask will maintain hygiene on the inside of PAPR hoods. Secondly, without a N95 mask, the wearer will be totally unprotected in the event the PAPR fails or malfunctions. Lastly, air exiting from the PAPR mask is not filtered and thus may contaminate a sterile surgical field with the operator's respiratory secretions. If surgical field sterility is a major concern, one should consider using PAPR models fitted with exhalation filters.

We have also found it useful to tape down the breathing hose leading from the blower unit to the hood, which may otherwise work itself loose from under the sterile gown to contaminate the operative field. In addition, although the PAPR is worn underneath the sterile gown, the blower unit must be exposed to allow entry of air through the filters (Fig. 3). Care must be taken not to compromise sterility of the operative field.

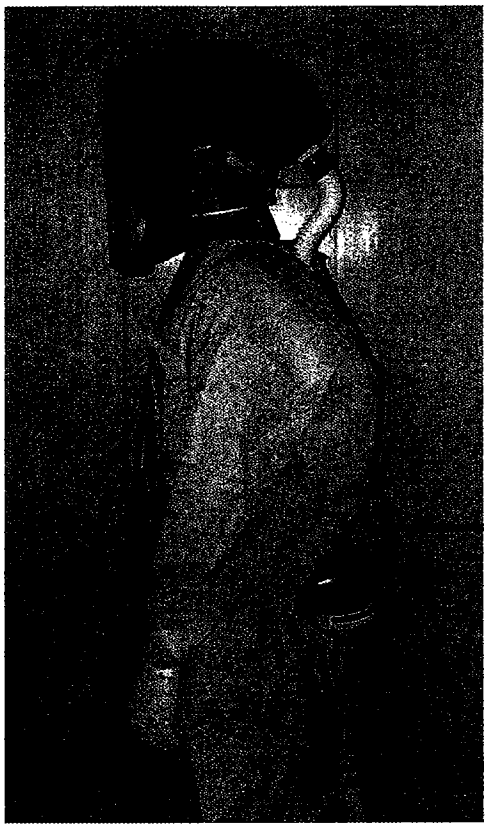

Figure 3. Radiologist with PAPR unit, after donning sterile gown. The gown is worn outside the PAPR but the blower unit and air filters are left exposed so as not to impede the intake of air.

IR Procedures in SARS Patients: Tan Tock Seng Hospital (TTSH) Experience

Being the tertiary referral center for treatment of tuberculosis, and co-located with the Singapore Communicable Disease Center, TTSH was naturally the hospital designated to treat SARS patients in Singapore.

In the period between March 15, 2003 and May 31, 2003, a total of 28 interventional procedures were performed in 27 patients out of the cohort of 206 SARS patients. Twelve ultrasound-guided pleural drainages were performed for symptomatic pleural effusions. There were also 12 requests for venous access, comprising 4 temporary dialysis catheters and 8 peripherally inserted central catheters (the 4 who required dialysis catheters all had underlying chronic renal failure). A guidewire lost during a bedside insertion of a central catheter was successfully retrieved in one patient.

An IVC filter was deployed in one patient who developed lower limb deep vein thrombosis. Anticoagulation was contraindicated in this patient because of concomitant bleeding through the rectum. Among our patients was one with an inoperable Klatskin cholangiocarcinoma. He had previous endoscopic right biliary duct stenting, but attempts at stenting the left biliary tree were not successful. A percutaneous left duct drainage followed by stenting was performed for this patient by the interventional radiologist.

All procedures were done outside the main radiology department and at the patient's bedside whenever possible. Therefore the 12 ultrasound-guided pleural drainages were thus carried out, employing full protective gear including PAPR. Procedures requiring fluoroscopy or angiography were performed at one of two locations. Minor procedures were done in a designated procedure room located within a

SARS intensive-care ward using a portable fluoroscopic C-arm unit (Opescope WHA50 C-arm, Shimadzu Medical Systems, Torrance, CA). Under normal circumstances, this room was used for cardiac pacing, being located in what was previously the coronary care unit. With minimal adaptation, the room was adequate for fluoroscopic-guided procedures including deployment of the IVC filter and retrieval of a lost guidewire. The other location where more complex fluoroscopic procedures could be performed was in a dedicated SARS operating theatre suite. A portable fluoroscopic C-arm unit (BV300, Philips Medical Systems, Best, Netherlands) capable of obtaining digital subtraction images was used. This theatre was primarily used for surgical operations and only the percutaneous biliary drainage and stenting was performed here.

These procedures were carried out employing the infection control measures mentioned above. No SARS infections to HCW were attributable to any of these procedures, a testament of the effectiveness of control measures to protect and prevent transmission of disease.

Long-term Implications for IR

Our recent experience highlights the importance of infection control in IR. Measures like washing of hands, proper use of PPE and thorough cleaning of the interventional suite after each case must immediately become routine in our daily practice. Clearly the days of simply donning a surgical gown over our office attire to quickly perform an interventional procedure in between reporting a pile of plain radiographs are numbered. Workflows and patient scheduling will have to be completely reevaluated. Instead of merely trying to achieve a high turnover, the schedule will have to take into account segregation of more healthy outpatients and elective inpatients from the more ill inpatients. Spatial segregation if different facilities are available would be ideal, otherwise a temporal segregation with emphasis on traffic control, provision of holding areas and redesign of waiting areas would be a feasible alternative. The schedule should also take into account stratification of risks from the infection control viewpoint, so that febrile patients and abscess drainages should be performed at the end of the list or in a designated room.

Room ventilation can be improved fairly quickly through installation of HEPA filters or even with portable filter systems. Other infrastructure modifications such as controlled access with an isolated sterile environment may not be immediately achievable but must now be anticipated to take advantage of the next renovation or when new equipment is acquired.

Emergency planning and crisis management will now also have to include planning for scenarios where a major infectious disease outbreak occurs. The planning will have to define various levels of alerts and the appropriate level of infection control measures required. Incorporated into the planning will be a regular infection control program which includes staff education, training and compliance monitoring. Mask fitting of N95 masks should be performed in anticipation of an outbreak so that all staff are aware of their mask size and familiar with wearing such apparatus. The more prepared staff are, the better they will respond during an acute outbreak.

CDC's interim guidelines on protection of HCW offer a wealth of information and recommendations. Some of these are not yet evidence based and may be costly to implement. Studies to identify minimal requirements for effective prevention of transmission would be an invaluable contribution to research of this relatively unknown disease.

Conclusion

The unfortunate truth about infection control and universal precautions in IR is that it is not universal. In a national survey of interventional radiologists on infection control, less than one-third adopted the consistent use of proper face and eye shielding during procedures [13]. Some do not even scrub with disinfectant before putting on sterile gloves [14]. Even as recently as 5 years ago, this journal published a commentary on the debate surrounding the use of surgical face masks during interventional endovascular procedures [15]. This was followed by a plea from Joffre et al. [16] for interventional radiologists to embrace a surgical conscience and adopt stricter infection-control procedures.

Several issues have been raised in this report, many of which require a change on our part. The impact of adopting these control measures should not be underestimated. It will undoubtedly increase the cost of health care delivery, prolong procedure time and even introduce new technical difficulties. On the other hand, we have seen the potential harm an infection such as SARS can have on the health care system. Even when SARS is subsequently controlled globally, we have to be prepared to confront the threat of other new emerging infections. In the true spirit of IR, we need to adapt, innovate and manage these issues so as to ensure the survival of our specialty. Habits are difficult to change and change is sometimes not welcome. A small agent in the shape of a coronavirus, although most definitely not a godsend, may just provide the impetus for change.

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