

# Severe Acute Respiratory Syndrome in a Naval Diver

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Severe acute respiratory syndrome (SARS) is a highly infectious, rapidly progressive, emerging disease. Early diagnosis and preventive measures are key for treatment and minimization of secondary spread. In the context of the armed forces, aggressive containment measures are essential to prevent an outbreak. In this study, we present the first reported case, to our knowledge, of SARS in a naval diver. The special physical requirements for divers and the potential complications associated with deep sea diving necessitate extensive investigation before certification of fitness for diving after SARS. In the early recovery period, potential problems during diving are caused by inadequate lung ventilation in relation to exercise level and increased breathing resistance attributable to weak respiratory muscles, with corresponding risk of hypoxia and hypercapnia, as well as decreased ability to respond to nonrespiratory problems during diving. Problems in the late recovery period include increased risk of diving complications (such as pulmonary barotrauma) resulting from fibrosis and scarring within the lung parenchyma, which are known complications of SARS. From our experience, we suggest that computed tomographic scans of the thorax, lung function tests, and careful follow-up monitoring should play a vital role in the assessment of patients during the convalescent period, before certification of fitness to dive.

## Introduction

Severe acute respiratory syndrome (SARS) is an emerging infectious disease that was first reported in Guangdong Province in southern China in November 2002 and subsequently caused outbreaks in Singapore, Hong Kong, Southeast Asia, and Canada.<sup>1,2</sup> The outbreaks not only resulted in many fatalities and hospitalizations but also had a huge economic impact on the nations involved, because of decreased revenue from tourism and industry. Although no other outbreaks have been reported since then, continued vigilance is essential in the event of future epidemics. To our knowledge, this is the first report of SARS in an occupational (naval) diver.

## Case Report

A 35-year-old Chinese man, working as a naval diver, presented to his primary care physician with fever 2 days after attending his mother's funeral. He first presented with symptoms on April 19, 2004, during the height of the SARS outbreak in Singapore. There was no travel history of note. His mother, who had had no previous medical problems, had collapsed suddenly and died at home after the onset of fever 3 days earlier,

with no other symptoms. She had sought medical attention from her family doctor but was never formally diagnosed as having SARS. Although SARS was suspected as the cause of her fever, this was never proven; she had not been hospitalized because of the rapid progression of illness.

The patient was referred to the emergency department of a tertiary hospital and subsequently hospitalized for suspected SARS because of his complaint of fever and his positive contact history. Table I shows the case definitions defined in Singapore by the Ministry of Health during the SARS outbreak and the actions to be taken. In all, the patient's father, sister, three nieces, sister-in-law, and girlfriend were admitted as part of an infected family cluster (Fig. 1). The provisional diagnosis was SARS. The patient's father eventually died after 5 days in the hospital; however, other family members made uncomplicated recoveries.

The patient continued to have a fluctuating fever while he was hospitalized, and he complained of loss of appetite and loss of weight. However, he never developed shortness of breath or other respiratory symptoms. The patient was evaluated for other causes of febrile illness, including community-acquired pneumonia, malaria, dengue fever, rickettsial illness, and pulmonary tuberculosis. However, all tests were negative. The patient was treated with intravenously administered, broad-spectrum antibiotics (levofloxacin and then ceftriaxone and clarithromycin) and required oxygen supplementation for several days. However, he never required intensive care or mechanical ventilation.

The diagnosis of SARS was initially made clinically but later confirmed radiologically and serologically. On the fifth day of admission, the patient's chest X-ray showed infiltrates consistent with SARS. The SARS coronavirus serological test was negative on admission but became positive 1 week after admission. The patient showed improvement and was discharged after a 17-day stay in the hospital. After discharge, he was quarantined for 21 days according to protocol.

During review in our department after the quarantine period, the patient was deemed unfit to dive because of abnormal lung function test results (Table II). The patient was otherwise well, and physical examination results were normal. However, the patient complained of dyspnea on exertion. Because he was a naval diver, the patient was referred for a respiratory consultation. A computed tomographic (CT) scan of the thorax 6 weeks after discharge showed no significant residual pathological condition. A high-resolution CT scan of the thorax 2 months after the initial CT scan also showed no abnormality. Results of a follow-up lung function test 5 months after discharge were normal. On the basis of all of these investigations, the patient was discharged from follow-up care by the respiratory physician. The patient gradually recovered and regained his normal fitness during the convalescent period. He passed chamber bounce

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**TABLE I**  
CASE DEFINITIONS OF SARS, AS DEFINED BY THE MINISTRY OF HEALTH IN SINGAPORE DURING THE SARS OUTBREAK

	Clinical Features	Travel/Contact History	Actions by Singapore Armed Forces
Probable SARS	Fever (>38°C) and one or more respiratory symptoms or symptoms associated with SARS and X-ray changes of pneumonia or autopsy findings consistent with pneumonia or ARDS without an identifiable cause	Positive travel to SARS-affected country or close contact with a probable SARS case in preceding 10 days or positive PCR or serological test for coronavirus	(1) Contact tracing; (2) medical leave; (3) home quarantine order
Suspect SARS	Fever and one or more respiratory symptoms or symptoms associated with SARS	Positive travel to SARS-affected country or close contact with a probable SARS case in the preceding 10 days	
Observation for SARS 1	Atypical pneumonia pending confirmatory investigations and response to antibiotics	None	
Observation for SARS 2	Unexplained fever (>38°C)	Positive travel history in preceding 10 days or close contact with a probable SARS case in the preceding 10 days	(1) Contact tracing; (2) medical leave with telephone surveillance for 10 days
Observation for SARS 3	Unexplained fever (>38°C)	Clustering of ≥2 cases in a health care facility, home, or work area	(1) Contact tracing; (2) observation
Observation for SARS 4	Unexplained fever with clinical presentation suggesting SARS	None	
Observation	Fever, features do not suggest SARS	None	No further action

ARDS, acute respiratory distress syndrome; PCR, polymerase chain reaction.

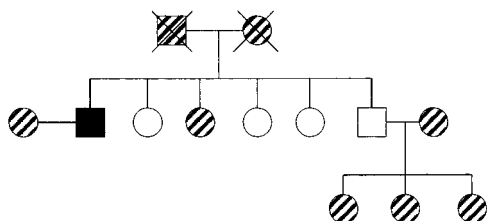


Fig. 1. Family tree showing infected family cluster. A total of seven family members were admitted for isolation. All recovered except for the father of the patient, who died. Black shading represents the patient, and hatching represents infected family members.

dives at 10 m and 50 m and was subsequently certified fit to dive 6 months after quarantine. He is currently well and has not had problems diving since then.

**Preventive Measures**

Certain preventive measures to prevent the spread of SARS were taken after diagnosis of this patient. Principles of control against SARS focused on three levels of containment, i.e., (1) public health response and medical care, (2) organizational and administrative measures, and (3) social and personal adaptations. Therefore, our goals were twofold: (1) to detect SARS cases early and to break any chain of transmission and (2) to prevent the onset of infection. Public health measures included contact tracing and close monitoring of personnel who might have been exposed to the index case. Contact tracing was performed up to 1 week before admission for all individuals in proximity to the patient. Personnel who were in contact with the patient were required to monitor their temperature 3 times per day and were quarantined at home. Organizational measures included re-

**TABLE II**  
LUNG FUNCTION TESTS PERFORMED 3 WEEKS AND 5 MONTHS AFTER DISCHARGE FROM THE HOSPITAL

Parameter	Percentage Predicted		% Change
	3 Weeks after Discharge	5 Months after Discharge	
VC	70	86	16
FVC	65	84	19
FEV <sub>1</sub>	67	85	18
FEV <sub>1</sub> /FVC	90	90	0
PEF	104	119	15

VC, vital capacity; FVC, forced vital capacity; FEV<sub>1</sub>, forced expiratory volume in 1 minute; PEF, peak expiratory flow.

stricted access and contact between divers and other camp personnel, to prevent the potential spread of infection. The temperatures of all personnel entering the diving unit were checked before entry. Contact of the diving unit with other personnel in the camp was restricted. Diving unit accommodations were made out of bounds to other personnel except medical staff members. In addition, different meal times for divers and other personnel were enforced. Other measures to prevent the spread of disease included not allowing utensils in the cookhouse to be reused on the same day and having divers leave the camp at different times from other personnel. In the week following diagnosis of SARS in this patient, only essential personnel in the diving unit were required to report to work to prevent the possible spread of SARS. Personal measures included isolation of the index case after diagnosis and quarantine for 21 days after discharge from the hospital.

## Clinical Aspects

The etiology of SARS has been linked to a novel coronavirus,<sup>3,4</sup> which was postulated to have crossed the species barrier from animal to human. This hypothesis is supported by reports that some of the early patients in Guangdong reported a history of occupational exposure to live caged animals, which were consumed as exotic "game food." The SARS coronavirus was also isolated from Himalayan wild civets.<sup>5</sup> Most of the cases resulted from "super-spreading events," in which some particularly infectious individuals were ultimately responsible for spreading the disease to tens of people.

The mean incubation period has been reported as 6 days, with a maximal incubation period of 14 days.<sup>6</sup> The primary mode of transmission is through direct or indirect contact with mucous membranes through infectious respiratory droplets and fomites.<sup>7</sup> Common presenting symptoms include fever, nonspecific symptoms (such as myalgia, malaise, and chest pain), anorexia, and respiratory symptoms (such as dyspnea). In early cases, the disease was misdiagnosed as a form of atypical pneumonia, with disastrous results.

Other findings reported include lymphopenia, thrombocytopenia, increased D-dimer levels, and increased activated partial thromboplastin time. In addition, deranged transaminase levels and elevated creatine kinase and lactate dehydrogenase levels were reported.<sup>7</sup> Chest X-ray findings, which provide clinical suspicion for SARS, include ground glass opacities, consolidation, and nodular and reticular opacities.<sup>8</sup> However, the standard for retrospective confirmation of infection is seroconversion in a whole-virus immunoassay (immunofluorescence assay or enzyme-linked immunosorbent assay). Unfortunately, serological testing is positive only after the first week of illness.<sup>7</sup> Interestingly, a recent study demonstrated that polymerase chain reaction testing of tears could confirm infection in the first week of illness.<sup>9</sup>

Age and coexisting illness have been reported as being prognostic factors for risk of death and the need for intensive care.<sup>7</sup> Treatment rendered has largely been supportive. Before serological diagnosis, empiric, broad-spectrum, antibiotic therapy aimed at both typical and atypical pneumonias is indicated. Although there is no definite cure for SARS, steroids and ribavirin have been used in some centers, with varying results.<sup>7</sup> The patient's pulmonary condition is monitored with serial chest X-rays, with ventilatory support as needed. However, prevention is paramount. Measures such as hand-washing, universal precautions, and public education are key to preventing the spread of SARS.

## Discussion

An infectious disease outbreak is a very real possibility in the armed forces because of the proximity of men and women living and working together for prolonged periods. In the context of a highly virulent and infectious disease such as SARS, an outbreak can lead to very high morbidity and mortality rates, as well as incapacitation of operational units. Therefore, prompt treatment and containment of spread are essential preventive measures. Other important measures include contact tracing, home quarantine, and widespread use of universal precautions. Lastly, a high index of suspicion must be maintained. For this patient, aggressive containment measures successfully prevented the spread of SARS to other unit personnel.

Because this patient was a naval diver, his convalescence and recertification for fitness to dive were particularly prolonged. Fortunately, he made a full uncomplicated recovery. Much of this could have been attributable to his young age and above-average fitness as a diver, as well as the lack of other comorbidities. Because there are no reports defining the effect of SARS on fitness to dive, we postulate two categories of effect.

First, there is the early recovery period. Immediate problems during diving would include increased risk of hypoxia and hypercapnia because of inadequate lung ventilation in relation to exercise level. In addition, there would be increased breathing resistance attributable to weak respiratory muscles being unable to overcome the normal flow resistance of the breathing apparatus. This would lead to impaired ability to respond to nonrespiratory problems during diving, with a corresponding decreased ability to compensate because of poor residual lung function.

Second, there is the late recovery period. Long-term problems would include increased risk of diving complications such as pulmonary barotrauma, resulting from decreased lung compliance and gas trapping as a result of fibrosis and scarring within the lung parenchyma, which are known complications of SARS. On the basis of our experience, we suggest that CT scans of the thorax and lung function tests should play a vital role in the assessment of such patients during the convalescent period before certification of fitness to dive. Our experience has also shown that an individual is more susceptible to respiratory infections after contracting SARS. All of these potential problems would necessitate careful follow-up monitoring of service personnel after infection by SARS or future emerging respiratory pathogens before certification of fitness for diving.

## Conclusions

The management of SARS in the armed forces is unique because of the increased potential for an outbreak. Preventive measures are essential to prevent the spread of the disease. Divers affected by SARS must be thoroughly investigated before they are allowed to resume their vocation, because of the potential problems posed after infection by SARS.

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