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Mass Casualty Incident Response and Aeromedical Evacuation in Antarctica

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Antarctica is one of the most remote regions on Earth. Mass casualty incident (MCI) responses in Antarctica are prone to complications from multiple environmental and operational challenges. This review of the current status of MCI risks and response strategies for Antarctica focuses on aeromedical evacuation, a critical component of many possible MCI scenarios. Extreme cold and weather, a lack of medical resources and a multitude of disparate international bases all exert unique demands on MCI response planning. Increasing cruise ship traffic is also escalating the risk of MCI occurrence. To be successful, MCI response must be well coordinated and undertaken by trained rescuers, especially in the setting of Antarctica. Helicopter rescue or aeromedical evacuation of victims to off-continent facilities may be necessary. Currently, military forces have the greatest capacity for mass air evacuation. Specific risks that are likely to occur include structure collapses, vehicle incapacitations, vehicle crashes and fires. All of these events pose concomitant risks of hypothermia among both victims and rescuers. Antarctica's unique environment requires flexible yet robust MCI response planning among the many entities in operation on the continent. [West J Emerg Med. 2011;12(1):37-42.]

BACKGROUND

Antarctica, covered almost entirely by massive sheets of ice, is one of the most remote and challenging environments on Earth.¹ Its importance in scientific research and exploration has led many nations to develop interests in the region. The Antarctic Treaty, in effect since 1961, has 47 signatory nations that assert their dedication to maintain Antarctica as a continent devoted to peaceful and scientific pursuits. Any military operations are restricted to peaceful support missions.²

Approximately 30 nations operate more than 80 research stations in the region, mostly near the coast. Nearly half of the stations operate only during the summer months. On the central plateau, only the United States' (U.S.) South Pole Station operates year-round through the dark six months of winter.³

Tourism represents a relatively new development in the Antarctic environment. Tourism is rising significantly around the region on a yearly basis, and the risk of tour boat disasters is therefore increasing. Most ships carry medical personnel on board but have limited resources for dealing with a mass casualty situation.

OBJECTIVE

This paper reviews the current status of Antarctic mass casualty incident (MCI) risks and response strategies from the perspective of aeromedical evacuation. Due to its remoteness, evacuation of victims by air, both within and from the Antarctic region, is a critical component of a wide variety of response scenarios following a future MCI.

CHALLENGES TO MCI RESPONSE IN ANTARCTICA Environment

An MCI is a disaster that overwhelms local resources, which in Antarctica are already scarce. The Antarctic environment includes sub-zero temperatures, seasons of continuous darkness, and extraordinary storms, all of which require unique measures of preparedness.⁵

Although the potential for a disaster is present year-round, a large-scale MCI would be most likely to occur during the summer months of November through February because there are considerably more people in the region - approximately 5,000 on the continent and tens of thousands of tourists in the surrounding waters.⁶ The largest Antarctic base, the U.S.'s

McMurdo Station, holds approximately 1,400 people during the summer.

During the winter months, Antarctica experiences continuous darkness. Temperatures routinely sink below -50°C , as opposed to slightly below freezing in the summer. In winter there are about 1,000 inhabitants on the continent and essentially no tourists.⁷

Another challenge imposed by the Antarctic environment is that magnetic navigation is complicated by its proximity to the South Magnetic Pole, which is currently off the Antarctic coast in the Eastern Hemisphere. The Global Positioning System satellite network has greatly improved accurate navigation.

Distance

Distances between Antarctica and civilization are vast, which is perhaps the most formidable of all the challenges listed. Travel from McMurdo Station to the nearest city, 2,400 miles away in New Zealand, takes five hours by plane. The bases of the various nations are scattered, rudimentary and separated by thousands of miles of hostile expanse. This degree of isolation is unmatched by any other human settlement and causes inevitable delays and difficulties in mounting an MCI response.

Increasing Cruise Ship Tourism

Most Antarctic cruises embark from Ushuaia, Argentina, the world's southernmost city. Argentina and Chile have few facilities to assist distressed ships in the Antarctic area, although their Joint Antarctic Naval Patrol maintains a dedicated search and rescue presence every summer.⁸ Ships in Antarctic waters run aground, become trapped in pack ice, sink, catch fire, or break down on a yearly basis in the Southern Ocean. The nearest rescue vessels may be a day or more away. Although casualties have been rare to this point, thanks to well-provisioned lifeboats and emergency plans, a foundering ship could potentially create an enormous disaster in Antarctic waters.

Approximately 40,000 people visited Antarctica during the 2008-2009 season, representing a 400% increase relative to 14 years prior.⁹ Antarctic cruise ships are also getting larger; some carry up to 4,000 passengers. It would be difficult to rescue victims from a ship of that size, as most rescuing ships are far smaller and have limited capacity. The International Association of Antarctic Tour Operators (IAATO) has recently barred Antarctic landings for ships carrying more than 500 passengers; however, these guidelines are not internationally binding for non-IAATO members.

Prevention

The extreme difficulty in MCI response in Antarctica requires conscientious prevention measures. Strategies for preventing MCIs include extensive safety and training protocols and specialized equipment to withstand the climate.

Additionally, in the Antarctic Ocean, melting ice has opened new, uncharted coastal waters, and the Antarctic Treaty Consultative Meeting (ATCM) has identified improved Antarctic hydrography as a critical measure to prevent an MCI at sea.¹⁰

MASS CASUALTY INCIDENT RESPONSE

MCI Success

A successful MCI operation relies on clear, well-practiced protocols, good communication networks, and access to sufficient resources.^{11,12} When resources are overwhelmed, those unlikely to survive without immediate intensive care should not be resuscitated or transported, especially in an environment with such sparse resources and dangers from exposure as Antarctica.^{13,14} The capacity of the clinic or staging area for victims may be quickly exceeded, necessitating consideration of all available warm, lighted areas as potential treatment centers. Trauma victims not killed immediately during an MCI often succumb to a combination of hypovolemia, acidosis and coagulopathy within the first 24 hours. An additional concern in Antarctica is hypothermia, and patients in open areas are at particular risk. Resuscitation of critically injured patients awaiting evacuation must focus on rewarming and adequate early resuscitation to the extent feasible.

Coordination

Antarctica and the surrounding ocean are divided into five Search and Rescue Regions, each under the jurisdiction of a Rescue Coordination Center (RCC), based in New Zealand, Australia, South Africa, Argentina and Chile. Emergency radio beacons, coordinated by satellite using the Global Positioning System that can relay a signal to the nearest RCC, are mandatory on most sea and air vessels. Use of beacons could minimize the search phase of a search and rescue operation for a missing vehicle, thereby improving MCI response.¹⁵ For a ship or aircraft in distress, the RCC is tasked with locating vessels capable of responding and has authority to impel them by UN convention to assist with rescue efforts.¹⁶

Unlike maritime and aeronautical response to distress signals, there are no official agreements for cooperation in Antarctic land-based MCIs,¹⁷ although any nation with capacity to assist in an emergency can be reasonably expected to do so. Responsibility for land-based search and rescue is traditionally considered to be primarily that of the national Antarctic Program involved. The Antarctic Programs of other nations and the nearest of the five RCCs would be expected to provide assistance as required.¹⁵

The Antarctica Search and Rescue Workshop was created in 2008 to coordinate planning and response to an Antarctic MCI; they had their second meeting in 2009.^{15, 17} One goal of the workshop is to develop international agreements for land-based MCIs that have not yet been solidified. The yearly ATCM provides a forum for codifying

such agreements.^{9,10} Although objective preparedness for an unknown future event is difficult to measure, the workshops have provided for clearer understanding between bases of relative rescue capabilities, as well as analysis of multiple actual and hypothetical disaster scenarios from a collaborative perspective of all stakeholders.¹⁷

AEROMEDICAL EVACUATION

Short-Range Aeromedical Evacuation

An MCI occurring far from an Antarctic base may require rotary aircraft to transport patients to the nearest base for initial stabilization. Most bases have one or two helicopters in operation; McMurdo, the largest base, has four.¹⁸ Most helicopters in Antarctica are AS350 Squirrels and Bell 212s, which are both versatile and suited to rescue operations. Maritime vessels occasionally carry a helicopter as well.

Long-Range Aeromedical Evacuation

In MCIs most lives are initially saved by survivors and bystanders after an incident, rather than by medical crews. Air evacuation should therefore focus on decreasing mortality among the early survivors who are at risk of delayed death.¹⁹ This group is most likely to die from complications following trauma, such as internal hemorrhage, sepsis or multi-organ failure. Transferring these patients to advanced medical facilities can greatly increase their chance of survival.¹⁹ The most advanced medical facility on Antarctica is McMurdo General Hospital (Figure), which is essentially a basic clinic with little critical care capacity and no surgical capability.²⁰

Remote Aeromedical Response

Aeromedical responses to remote locations require more strategy and planning than responses to populated areas because there are fewer resources to rely on upon arrival.²¹ Difficulties in remote air evacuations potentially arise with communications, division of responsibility, unfamiliar terrain,



Figure. McMurdo General Hospital. Photo courtesy of Ken Iser-son, MD.

equipment problems, personnel problems, crew exhaustion, inclement weather and the difficult clinical decisions one is forced to make when faced with exiguous resources.^{19,22} In Antarctica, many types of aircraft cannot easily land on the continent's rough-hewn ice runways, so long-range Antarctic operations are accomplished by specialized military aircraft such as American C-130s and C-17s that have been fitted with ski-type landing gear.

Military Response Capacity

Militaries are under no statutory obligation to evacuate civilians. Nevertheless, most of the aeromedical evacuations from Antarctica in the past have been accomplished by military teams, and it can be assumed that military branches would deploy to play a crucial role in aeromedical response for an Antarctic MCI. International cooperation is critical for success.²³ The U.S. employs a system of Critical Care Air Transport Teams (CCATT), each consisting of a critical care physician, a critical care nurse and a respiratory therapist.^{24,25} Although surgical intervention is not feasible en route, the CCATT team operates as a portable intensive care team within a cargo aircraft. The most commonly used aircraft for the team is the C-130 Hercules, which has the capability to land on unimproved airfields and carry up to 74 litter patients. The C-130 is routinely flown to Antarctica with affixed skis. Another aircraft commonly used is the C-17 Globemaster. This aircraft is better suited to patient transfer than the C-130. Although it can only carry 36 litter patients, it flies higher and faster than the C-130 and offers better lighting and electrical power. It also improves patient transport with a warm environmental system and superior access to patients from both sides.

Airdrops

Aeromedical resources may also be used to deliver critical supplies via airdrop if landing is not possible. In the winter, cold and darkness preclude landing. In the winter of 1999 airdrops over South Pole station were used to deliver chemotherapy and biopsy equipment to the station's physician, who diagnosed herself with breast cancer during her winter over.²⁶ In 2007, an airdrop delivered engine parts to a disabled trawler in Antarctic waters, demonstrating this as a possible strategy in a maritime MCI as well.

Innovations in Aeromedical Response

Several advances in technology could hold promise for future Antarctic MCI responses. One such innovation is a mobile trauma center in the space of a 53-foot trailer that can fit in the cargo bay of a C-130J-30 (a lengthened C-130 cargo plane). This trailer is equipped with six critical care beds and seven noncritical beds.²⁷ An attached tent system can add 100 exterior beds, although low temperatures in Antarctica could limit the applicability of this feature. The trailer could be deployed as a stand-alone unit to respond to an MCI far from

base or as a critical care overflow area at the base. Bringing such medical resources to Antarctica could become necessary in a massive MCI where timely aeromedical evacuation is not possible. Adding heating units, a capable tow vehicle, and a specialized suspension could make this type of resource invaluable.

For rapid aeromedical evacuation, the Swedish National Air Medevac (SNAM) can convert any standard passenger airliner with no specialized features into an aeromedical evacuation aircraft within six hours by replacing seats with efficiently-designed intensive care beds and litter racks. After the 2004 Indian Ocean tsunami, SNAM outfitted three airliners with 92 beds that brought hospitalized patients back to Sweden five days post-disaster.²⁸ A similar strategy could be used in Antarctica if military evacuation capacity is exceeded or unavailable; however, attachment of skis for ice runway landings may be a complicating factor.

MCI SCENARIOS IN ANTARCTICA

Mass Impact or Structure Collapse

Mass trauma due to a large impact (such as from falling objects, snapping cables or malfunctioning machinery) or building collapse has yet to occur on the Antarctic continent. Although earthquakes are relatively uncommon in Antarctica, they do occur. In both 1998 and 2004, for example, very large earthquakes of magnitude 8.1 on the Richter scale struck off the coast.^{29,30} If structures collapse, extrication and sheltering efforts may be largely unassisted for a long period of time, exposing victims to dangerously cold temperatures in addition to their injuries.

Hypothermia threatens to strike rescuers as well as victims.³¹ The more practiced the local population is with outdoor rescue operation drills, the greater the chance of successful rescue when an MCI strikes, and the lower the chance of responders becoming victims themselves.

Vehicle Incapacitation

Ships, aircraft, and land-based vehicles are in use all over the Antarctic region. All are at risk of becoming remotely stranded or incapacitated. One such example includes the first cruise ship designed for Antarctica, the *MS Explorer*. The *Explorer* sank after striking ice in 2007.⁴ Three vessels were within 40 miles of the vessel and were activated by the Argentine RCC to respond immediately. More than 150 passengers and crew were rescued from the stricken ship.³² They were then transported to the nearest Antarctic base, from which they were flown to Punta Arenas in southern Chile. The evacuation took place in favorable weather and typical air temperatures of about -5°C. The only medical consequences were four cases of moderate hypothermia.

Much of the Antarctic Ocean remains uncharted, and coastal water is increasing as polar ice melts more than it refreezes each year. Ships face a multitude of hidden hazards including land, shoals, and icebergs. Increasing vessel traffic

has increased the risk of an MCI. Sudden calving of ice shelves can also pose a potential hazard to ships.

Helicopters may be very useful to locate and rescue victims. Although a sinking ship may be the most likely disaster scenario in Antarctica, long-range aeromedical evacuation in this situation has a limited role. In most situations, a ship in distress incurs few traumatic casualties and allows adequate time for lifeboat deployment. The largest risk is hypothermia, which is unlikely to benefit from air transport to a hospital off-continent.

Vehicle Crash

Air New Zealand flight 901 crashed into an Antarctic mountainside in November 1979 while conducting a routine sightseeing flight.³³ Weather conditions created a white-cloud backdrop behind the snow-covered Mount Erebus, creating a "sector whiteout." The aircraft's ground proximity warning sounded and the crew responded appropriately with upward pitch and full power, but it was too late. Six seconds later, a full-speed impact occurred, killing all aboard. Search aircraft found the wreckage 12 hours after the crash. Had there been evidence of any survivors, helicopter crews would likely have been deployed from New Zealand's Scott Base and the US's McMurdo Station, both about 40 miles from the crash site.

Another plane crash in 2007 resulted in only minor injuries.³⁴ In this case, the crash survivors were fortunate to have good weather, intact survival gear, functioning communications equipment and minimal injuries.

The potential for a vehicle crash is a real threat on the Antarctic continent. Land-based vehicles contend with uncertain terrain and poor visibility conditions. Aircraft face problems such as difficulty judging height above blinding white terrain, a runway system largely made up of unfinished, rutted ice fields, scant aeronautical resources, daunting weather conditions and extreme remoteness. Vehicle crashes in particular have the potential to cause MCIs very distant from any clinical resources. Helicopter rescue to the nearest base is the most likely response in this scenario. Alternatively, setting up a field stabilization center at a remote scene may be necessary for a large-scale MCI response; however, freezing weather conditions could render this strategy untenable.³⁵

Explosion or Fire

In Antarctica, the fuel caches and power generators that support the inhabitants are at risk of explosion. Structure fires and vehicle explosions also pose a risk of MCI. Water quickly freezes, requiring specialized chemicals to fight fires. Antarctica is a desert with very dry air that allows fire to spread quickly despite the cold. Occasional fires have occurred in Antarctica in the past. A large fire at the UK's Rothera Station in 2001 destroyed the laboratory. Luckily, there were no casualties. A Japanese whaling ship caught fire in 2007 off the coast, killing one person.³⁶ Also, in 2008 a fire at Russia's Progress Station killed one and injured two

people. Beyond the danger from injuries and burns, loss of an entire base to fire would be a devastating event because of the immediate threat of lethal hypothermia. McMurdo Fire Department and its counterparts at other bases are highly focused on prevention measures.

CONCLUSION

A wide variety of potential MCIs threaten Antarctica, and advanced planning is crucial to ensure the health and safety of the continent's population.³⁷ Rapid communication of the situation, conversion of local resources into triage centers,³⁵ efficient transportation of victims to base clinics,³⁸ consideration of supply and trauma team delivery to the MCI site, and air evacuation to off-continent medical facilities are all cornerstones for an effective Antarctic MCI response.^{39,40} Coordination between National Antarctic Programs and the five southernmost RCCs to these ends will improve chances for victim survival in the aftermath of a future Antarctic disaster.

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