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When all else fails: 21st century Amateur Radio as an emergency communications medium

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ABSTRACT

Twenty-first century demand for radio spectrum continues to increase with the explosive growth of wireless devices, but authorities reserve slices of the spectrum for licensed Amateur Radio operators, recognizing their value to the public, particularly with respect to providing emergency communications. Blood banking and transfusion medicine are among the specialties that should also recognize the value of Amateur Radio as an emergency communications medium, because blood collection, testing, processing, storage, and transfusion are life-saving activities that in modern times can be separated by considerable distance.

1. Introduction

Contemporary to Karl Landsteiner's serologic discovery of A, B, and O blood groups, Guglielmo Marconi was attempting trans-Atlantic wireless communication. Marconi succeeded in 1901, and shared the 1909 Nobel Prize in Physics with Ferdinand Braun, for contributing to the development of wireless telegraphy [1].

Wireless telegraphy (Morse code) was soon supplemented by wireless telephony (voice). Congestion arose as commercial and military interests competed with each other, and with amateur experimenters, all operating in the long wavelength, low frequency radio spectrum. Short wavelength, high frequency radio signals were thought to be ineffective for long distance communication, and posed other technical challenges as well. Regulations emerged to favor commercial and military interests, consigning amateurs to the "useless" wavelengths of 200 m and lower [2].

Amateurs were soon outperforming professionals, reliably communicating over longer distances with lower output power. It was known that long wavelength radio signals propagated along the curvature of the earth, with progressive decrease in signal strength. Amateurs discovered that shortwave radio signals traveled upward and were reflected back to earth by the ionosphere, with less signal loss. As this was understood, other radio services migrated to the shortwaves. Specific frequency allocations and licensing standards developed for all services, including the Amateur Radio Service [2].

Radio waves travel at the speed of light (c), which defines the inverse relationship between wavelength (λ) and frequency (f), such that $\lambda \times f = c$. Thus, the shortwave spectrum, in modern times defined as wavelengths from 100 to 10 m, is also called the high frequency spectrum, spanning 3–30 MHz (megahertz, where hertz = $\sec^{-1}$). Since Marconi's time, many technical challenges associated with even higher frequencies have been overcome, so the usable radio spectrum can be described as follows:

- Low frequency (LF), 30–300 kHz (includes time signal and radio navigation services).
- Medium frequency (MF), 300–3000 kHz (includes the AM broadcast band and Amateur Radio frequencies).
- High frequency (HF), 3–30 MHz (includes shortwave broadcasting, and Amateur Radio, aviation, land mobile, marine, and military communications).
- Very high frequency (VHF), 30–300 MHz (includes the FM broadcast band, television channels, Amateur Radio and other communication services).

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- Ultra high frequency (UHF), 300–3000 MHz (includes television channels, mobile phone service, Amateur Radio and other communication services, wireless LAN, and the microwave oven frequency of 2450 MHz or 2.45 GHz).

VHF and UHF amateur bands are most commonly used by licensed volunteers for local communication at events such as parades or marathons. Amateur ''repeater'' stations, with antennas on tall buildings, towers, or mountains, allow communication beyond the usual ''line-of-sight'' propagation characteristic of VHF and UHF radio waves. Amateur repeaters used for public service generally have backup power systems in place for uninterrupted operation when commercial power is lost. Repeaters can also be linked to each other, to the public telephone network, or to the Internet.

HF (shortwave) Amateur bands are used for emergency communication when distances beyond line-of-sight must be covered without the benefit of any infrastructure. Nature, rather than human artifice, provides the means. The ionosphere reflects (or, more precisely, refracts) HF radio waves so that signals sent skyward can reach a receiving station beyond the horizon of the transmitting station. The extent to which refraction occurs depends on the radio frequency and the condition of the ionosphere, which in turn depends on the time of day (for exposure to ionizing solar radiation), sunspot number, and other factors related to solar activity. Amateur Radio operators have empirically understood and exploited these variables for decades. In the twenty-first century, it is also common for operators to enhance their empirical understanding of ionospheric propagation with computer modeling. (As shown in Fig. 1, personal computers are an integral part of many Amateur Radio operating positions.) Thus, a sophisticated skill set that might otherwise be burdensome to acquire and hard to maintain is pursued with enthusiasm for recreational purposes. If and when disaster strikes, this is an example of the practical knowledge Amateur Radio operators can apply when asked to provide emergency communication for ''served agencies'' such as Red Cross Red Crescent Societies, the Salvation Army, healthcare facilities including blood banks, and other organizations involved in disaster response.

Fig. 1. This operating position is part of a health care professional's Amateur Radio station. The radio transceiver itself (lower left) uses digital technology for control and various stages of signal processing, much like a modern laboratory instrument. It can function independently, or be linked to a personal computer. Software exists for radio and antenna control, contact logging, shortwave propagation modeling, digital communication encoding and decoding, and passing message traffic to and from the Internet. Photo courtesy Dr. Scott Wright, Mayo Clinic cardiologist, used with permission.

2. Recent examples of Amateur Radio emergency communication

The work of licensed radio amateurs in disaster response and emergency communication is reported primarily in the specialty literature of Amateur Radio itself. English-language journals include CQ and World Radio (CQ Communications, Hicksville, New York, USA) and QST (ARRL, the National Association for Amateur Radio, Newington, Connecticut, USA). Print and digital editions of these publications are available. QST publishes a monthly public service column and an annual (issue 9 of 12) theme section devoted to disaster response and emergency communication. Timely reports may appear in any issue of these and other journals published by Amateur Radio societies around the world.

The June 2011 issue of QST (volume 95, issue 6) published an early report of Amateur Radio operators responding to the Great East Japan Earthquake of March 11. Where commercial electricity was interrupted, Japanese amateurs powered their stations with car batteries or portable generators to transmit rescue requests, information on refugee centers and their needs, infrastructure conditions, and availability of supplies. Shortwave frequencies in the 7 MHz (40 m) and 3.5 MHz (80 m) amateur bands were designated for emergency communications in and out of affected areas. The Japan Amateur Radio League (JARL) activated its regional stations in Tokyo, Osaka, and Sendai (in Miyagi Prefecture, near the magnitude 9.0 earthquake epicenter). Within affected areas, Japan's Ministry of Internal Affairs approved the use of hundreds of additional VHF/UHF transceivers for local communication [3].

As reports were being published about the Great East Japan Earthquake, America's ''Tornado Alley'' was active. On May 22, 2011, one of the deadliest tornadoes in history swept through Joplin, Missouri and slammed into St. John's Regional Medical Center. Amateur Radio operators responded to requests from the American Red Cross and local hospitals to provide emergency communication. Cell phone coverage was described as spotty at best, but mostly non-existent. Landline telephone service was also interrupted, so Freeman Health System in Joplin called on Amateur Radio operators to facilitate communication with hospitals in Springfield, Missouri, 70 miles east, so Freeman could evacuate chronic patients and make room for emergency cases [4].

Concurrent with the Joplin tornado report was a description of the 114th and 115th activations of the Amateur Radio Emergency Service (ARES) Hospital Disaster Support Communication System (HDSCS) of Orange County, California. The 114th activation of HDSCS, on March 21, 2011, was for Children's Hospital of Orange

County (CHOC), after a power surge caused the hospital's computer-controlled phone service to fail. Amateur Radio operators familiar with CHOC from prior drills and actual emergencies came quickly to communicate on behalf of the emergency department, NICU, PICU, pharmacy, and other important units. The HDSCS leader herself handled several critical messages, including one about an incoming acute surgical patient. The 115th activation of HDSCS was also in response to a telephone system failure. Saddleback Hospital in Laguna Hills lost inbound and outbound trunk lines for nearly 8 h on April 5, 2011, so Amateur Radio operators provided essential communication with ambulance services and other hospitals [5].

Although Amateur Radio has its origins in Morse code and voice communications, digital text and image modes have also been adopted, and adapted, by radio amateurs. Digital modes can provide levels of security, accuracy, and interoperability with the Internet that are especially useful to healthcare providers. An example can be drawn from the Bethesda Hospitals' Emergency Preparedness Partnership (BHEPP), created in the Washington, DC area in 2004 by the National Naval Medical Center (NNMC), the National Institutes of Health Clinical Center (NIHCC), and the Suburban-Johns Hopkins Hospital. The National Library of Medicine (NLM) joined BHEPP in 2008, and asked Amateur Radio operators to develop an emergency e-mail system to link participating hospitals to the Internet using shortwave frequencies (Fig. 2). Shortwave frequencies were deemed essential, as they provide long distance communication without intervening infrastructure, and the project anticipated events as widespread and disruptive as Hurricane Katrina was in 2005 [6].

The aforementioned BHEPP project was funded as one of several research, development, and infrastructure projects [6]. On the other hand, projects without external financial support can also produce outstanding results. A case in point comes from an objective, third party report of how an experienced radio amateur in Florida built a highly mobile emergency service van capable of voice, data, and video communication on all major Amateur Radio bands. In addition, the van can hold enough food and water to support two operators for five days. The private owner/designer wanted to prove to local governments that "*Bigger* is not always *better*." His US$65,000 van has outperformed million-dollar mobile command posts designed under government contract [7].

Amateur-built communications vans were also used during the Colorado wild fires of June and July 2012. An especially valuable Amateur Radio asset in wild fire response is the ability of amateurs to send visible and infrared video images to emergency operations centers. Besides monitoring the progress of fires, and the effect of interventions, amateur TV crews could spot endangered residences through telephoto lenses and, using GPS coordinates and compass directions, guide airborne tankers and rescue teams [8,9].

Like the June–July 2012 wildfires in Colorado, Hurricane Sandy's arrival on the United States Atlantic Coast in October, 2012 required weeks-long effort by Amateur Radio volunteers. Many of the amateurs themselves suffered great losses, but were able to address their own needs and the needs of others as a result of preparation, training, and specialized equipment such as emergency power sources. Wide areas were without electric power, cellular and landline telephone service, cable TV and Internet because of the storm. In a recent report pertaining to Hurricane Sandy, it was noted that permanent Amateur Radio antennas previously installed at hospitals and shelters were invaluable for ensuring reliable emergency communication during the disaster response [10,11].

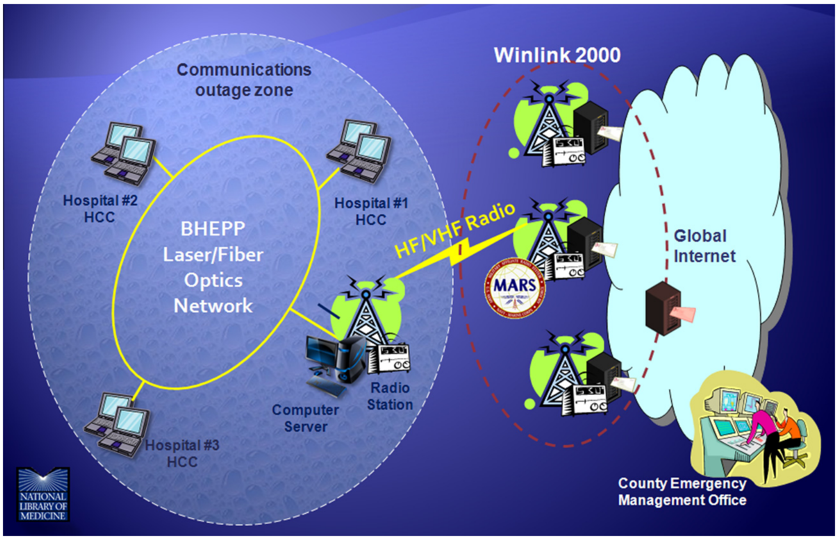

Fig. 2. A healthcare Intranet can be linked to the outside world via HF and VHF radio when conventional infrastructure is rendered inoperative. This figure is from the public domain version of Cid and Mitz [6], and is used with authors' permission. BHEPP: Bethesda Hospitals' Emergency Preparedness Partnership. MARS: Military Auxiliary Radio System, a civilian Amateur Radio program sponsored by the US Department of Defense. Winlink 2000: Global Radio Email System supported by licensed radio amateurs.

Table 1
Organizations and pertinent web addresses relevant to Amateur Radio emergency communications for health care facilities, including blood banks and transfusion services.

Organization	Pertinent web address
ARRL, the National Association for Amateur Radio (USA)	www.arrl.org/public-service
IARU, International Amateur Radio Union	www.iaru.org/emergency-communications.html
HDSCS, Hospital Disaster Support Communications System	www.hdscs.org
BHEPP, Bethesda Hospitals' Emergency Preparedness Partnership	www.bethesdahospitalsemergencypartnership.org
CBBS, California Blood Bank Society	www.cbbsweb.org/links/disaster_plan.html
Winlink 2000 Global Radio Email System	www.winlink.org/EmComm

3. Amateur Radio activities pertinent to disaster response

As an avocation, Amateur Radio encompasses recreational activities apart from public service, but nevertheless applicable to emergency communication. Here, "recreational" and "leisure" activities should be distinguished. Casual conversation with other radio amateurs tends to be a leisurely recreation. Recreation becomes more challenging outside the comfort of one's home. Small radios with self-contained batteries can support worldwide communication, but sustained and reliable operation entails more (Fig. 3). Related to this, ARRL, the National Association for Amateur Radio in the United States, sponsors an annual activity called Field Day, during which operators assemble stations where no other radios or antennas are permanently in place. Field Day proceeds as a contest, with participants attempting to contact as many other stations in as many US states and Canadian provinces as possible. Contest points increase for such things as using renewable energy sources, communicating via an Amateur Radio satellite, sending and receiving text in the official format used for third-party messages, and receiving visits from government or served agency representatives. In the words of ARRL Chief Executive David Sumner, "Field Day is, without question, the largest on-air event in Amateur Radio. Its roots are in the efforts of hams to exercise their emergency communication skills, starting with the first Field Day many decades ago. Emergency preparedness is still at the core of Field Day" [12].

Social aspects of Field Day, such as meals shared among radio operators, family members, and guests also enhance disaster response capabilities. For example, after Hurricane Sandy interrupted natural gas and electricity, a radio amateur took his mobile barbeque grill through neighborhoods, allowing residents to grill foods that would otherwise spoil [10].

Although ARRL Field Day is primarily a North American activity, similar exercises are held elsewhere in the world. Other contests, from home (Fig. 1) or portable (Fig. 3) stations, are international by design, with goals related to maximizing not only the number of two-way contacts, but also, their diversity, e.g., as measured by the number of different countries or geographic zones. The friendly competition embodied in these exercises makes them part of a broader category collectively referred to as *radiosport*. Radiosport also includes fox hunting, or radio orienteering, in which a hidden transmitter must be located. Fox hunting skills are applicable to locating the source of any radio signal, not just one on an amateur frequency. A recent report describes how fox hunting likely prevented a house fire [13].

Healthcare professionals seem to be disproportionately represented in an aspect of Amateur Radio called DXpeditioning. This can be as simple as doing Amateur Radio from a comfortable vacation destination, as one of us (KN) did in Guam with members of the Tokyo International Amateur Radio Association. DXpeditioning can also coincide with medical and/or educational projects, such as a 2001 visit to Bhutan by seven Amateur Radio operators, of whom four were medical doctors, including NASA astronaut Dr. Chuck Brady (1951–2006) [14]. In its extreme, DXpeditioning compels otherwise sensible healthcare professionals like Mayo Health Systems' Dr. Glenn Johnson to join groups that put uninhabited – and virtually uninhabitable – places like Heard Island (1997), Desecheo Island (2009), and Malpelo Island (2012) on the air for days to weeks. The discipline and logistical skills required for such undertakings surely contribute to one's

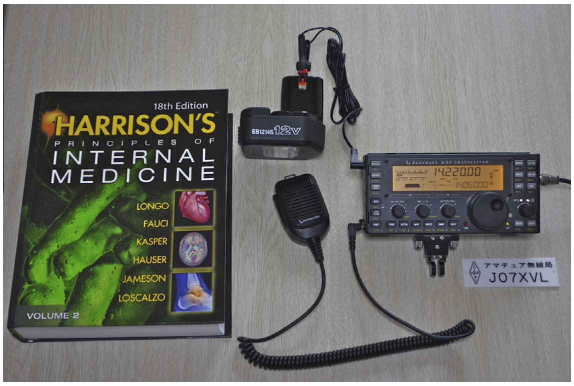

Fig. 3. Bigger than a cell phone but smaller than Harrison's, this Amateur Radio transceiver is capable of world-wide communication via the ionosphere – no infrastructure required. Operable with internal batteries, the transceiver can also be powered by an external source of 9–15 V, in this case, a cordless drill battery pack pressed into service to provide extended operating time. The protuberance at the bottom is a detachable "paddle" telegraph key, controlled by an operator's thumb and forefinger. Morse code can be transmitted directly (especially, as an alternative to voice when radio propagation is poor), or the transceiver's firmware can convert the operator's Morse code into error-free digital transmissions. This radio can also decode and display incoming Morse and digital data without being linked to a computer. Author (KN) photo.

ability to survive, and communicate, in the adverse situations associated with a disaster.

4. Discussion

This report is intended to introduce, or re-introduce, Amateur Radio as an emergency communications medium of value to health care institutions. Pertinent organizations with frequently updated websites are listed in Table 1 to complement the bibliography. Some blood bank and transfusion medicine specialists may have prior exposure to Amateur Radio. The authors' experience in Japan and the United States is that Red Cross facilities often host Amateur Radio stations as part of their disaster response mission. As the complexity of blood banking has increased, however, administrative and physical distances have separated Red Cross disaster response and blood center operations, so Amateur Radio may now be a less familiar entity to blood bank and transfusion specialists. On the other hand, the California Blood Bank Society (CBBS) specifically includes Amateur Radio in its disaster response plan, and the CBBS Northern, Central, and Southern Area Emergency Operations Centers (AEOCs) are hosted by independent blood centers [15,16]. Likewise, a chapter is devoted to Amateur Radio in a modern textbook on hospital preparation for bioterror [17].

The history of Amateur Radio, like the history of blood banking and transfusion medicine, includes progress through various stages of improvisation. A culture of improvisation that persists in Amateur Radio may seem to be at odds with the culture of compliance that permeates modern blood banking and transfusion practice, but essential elements of Amateur Radio are guided by rules, regulations, and peer pressure that favor safe, effective, and courteous operation. In times of disaster, however, an Amateur Radio operator, like a good healthcare professional, will put the safety of others first, and improvise with one's own circumstances to serve a greater good.

Some healthcare professionals may believe that prospective Amateur Radio operators must demonstrate competence in Morse code to earn a license. This 20th century truth has been phased out since the International Telecommunications Union (a division of the United Nations) eliminated Morse code competency as a prerequisite for access to the shortwave amateur bands. What remains for licensure is the need to show knowledge of essential rules, regulations, radio theory and practice, all of which are well within the learning scope of anyone with a responsible position in blood banking or transfusion medicine. Thus, a suitably motivated person can, with modest effort, acquire avocational privileges with vocational impact.

This article has some obvious limitations. First, although Amateur Radio, and the ability of amateurs to provide emergency communication, is global, examples cited herein are from English-language reports of activity in Japan and the United States. The authors dare to imagine that colleagues elsewhere will be sufficiently annoyed by this bias to submit their own reports from other parts of the world. Second, the examples are representative rather than exhaustive, with a further bias to progressively illustrate the Amateur Radio capabilities of particular relevance to healthcare institutions. Some additional examples of effective and life-saving efforts are incorporated only by Refs. [18–25].

In conclusion, Amateur Radio in the 21st century is a modern and useful emergency communications medium. The authors lived and worked through Japan's 3.11 earthquake, tsunami, and nuclear power plant crisis [26–28]. One of us also lived and worked through America's 9.11 crisis [29]. Our direct responsibilities did not include radio communication in these instances, but the availability of Amateur Radio operators, when all else fails, was reassuring to us, and lifesaving to others.

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