The evolution of disaster medicine

As the frequency of disasters grows, novel technologies to help medical professionals in these situations must be developed. Here is a glimpse of some ideas that might revolutionise disaster medicine in the future

Disasters, regardless of their cause, have devastating effects on the ability of healthcare providers to deliver medical care to patients adequately. Recent catastrophic events, such as Hurricane Katrina in 2005 and the Fukushima Daiichi Nuclear Power Plant incident in 2011, make healthcare delivery extremely challenging, even in developed countries. Direct damage to hospital systems or issues with overcapacity can cripple healthcare delivery systems in times of the greatest need. As the frequency of natural and human-caused disasters grows, there is an imperative need to develop and implement novel technologies that can assist medical professionals in these situations.

Despite the development of new technology, disaster medicine response teams often rely on relatively antiquated technologies to respond. It is unclear whether this lack of adoption of new technologies is a result of opposition to the efficacy or ethics of the technology itself, or if it is related to potential financial burdens. However, as electronic devices continue to miniaturise, grow more powerful and become less expensive, it is inevitable that the way disaster medicine is practised will continue to evolve.

Through this review, we hope to provide a glimpse of the technology that has the potential to revolutionise the way disaster medicine is practised.

Trauma beyond limits

You are the first responder on the scene following a Category Four Hurricane. The local hospital has significant structural damage and the nearest regional hospital is hours away. You will need to use your basic EMS skills to triage the patients, see that they receive the proper care, and decide which resources will be needed. Initial management in this type of situation requires a solution that is mobile, easily applied, and scalable.

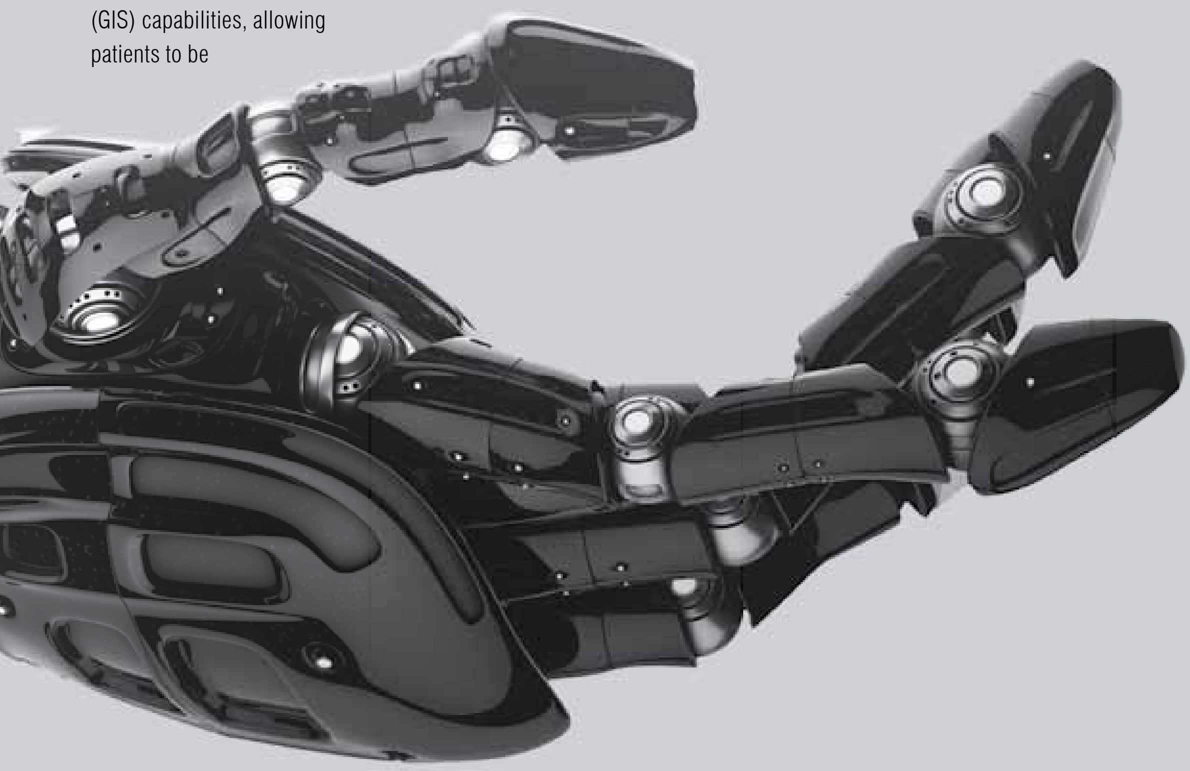
Electronic Triage Tags – Traditional response systems are paper-based, which limits the speed at which information can be collected and the level of detailed information that travels with the patient. For instance, some of the patients in the Haiti Earthquake of 2010 were transferred between field hospitals with only the information that could be written on their casts. Digital technologies present a solution for this type of problem. Their rapidly increasing computing power has led to their utilisation in the field of medicine through education and direct patient care.

Triaging is a key tenet of any emergency medical response. It involves determining the severity of the injury and the next step of care, and marking the patient according to acuity. Traditionally, this has been completed in the field using paper tags distinguished by colour that are updated as a healthcare worker periodically reassesses the patient. This system, while meeting the basic needs of triage, is inefficient, requires additional manpower and does not allow real-time monitoring of patients.

Having access to better technology such as the Electronic Triage System would allow first responders to utilise their time better, as well as to monitor casualties more efficiently. In this system, the patient is connected to a triage tag, that serves as a central hub for patient care. The tag is connected to remote sensors that can measure the patient's blood oxygen, blood pressure, heart rhythm (ECG), body temperature, end tidal CO_2 and even blood glucose. It reports

electronically to a central system where the data can be accessed in real-time by computer, mobile phone, or even wearable technology like Google Glass. The tag colour will reflect the severity of the disease (red = highest, blue = lowest).

The Electronic Triage Tag could provide additional features in addition to standard triaging functions. Since the tag is connected to the patient's unique identifier and is transferred with the patient as he or she moves through the medical system, it can potentially store medical information and avoid the lack of data transfer seen in the Haiti Earthquake response and which is experienced during most disasters. Moreover, the tags can also have geographic information system (GIS) capabilities, allowing patients to be tracked as they move through the system. This provides a more complete picture of the scope of damage and precise localisation of patients as supplies are delivered. First responders can utilise real-time technology to enable better assessment of patients, as well as establishing remote assistance on patient status. This can further provide a more sophisticated system for transferring high-risk patients to the appropriate healthcare facility.



Telecommunications and mobile phones – as the triaging process continues, physicians or other healthcare workers may need to visualise a patient's wounds. This can present a serious problem during situations in which it is too dangerous to bring additional healthcare workers to the scene. Telemedicine, or the use of telecommunication to provide healthcare, has become an important tool for physicians. Whether for astronauts in space or patients at a disaster scene, telemedicine is sometimes the only means for physicians to provide their care and expertise. It allows for medical care to be delivered no matter how remote casualties may be.

Some of the aforementioned Electronic Triage Systems can transmit live video or still photographs of patients, but there is a far more ubiquitous technology that can provide this type of care. With over 6.9 billion mobile phone users and 2.3 billion mobile broadband users globally, personal mobile technology is far more widely available than electronic triage tags. Applications such as FaceTime, Google Hangouts, and Skype allow patients and first responders to transmit live video to remote physicians who can help with initial triage, diagnose and assist with treatment. This technology also presents an opportunity for EMS to deliver updates and live video streams to emergency departments as ▶

patients are being transferred from the field to the hospital. In addition to video conferencing applications, a plethora of decision-support applications that have been developed to assist healthcare workers in every day practice can also help during disaster management. Applications such as PalmEM have built-in scoring systems that can be used to assist with triage and management decisions.

Mobile applications can also communicate with devices to help deliver care. For instance, as Electronic Triage Systems become more widely used, one can expect synchronisation programs to be developed that allow healthcare workers to follow the status of patients on their mobile devices.

We have also seen the development of portable, handheld ultrasound machines that can be used to check for internal bleeding and assist with difficult line placement – these images can be transmitted to a physician via a mobile phone.

As these portable systems continue to become more advanced, perhaps we will see the introduction of High Intensity Focused Ultrasound (HIFU), a tool that has been used in hospitals to focus ultrasound beams to vaporise tissue or stop bleeding. This would be an incredible asset that has great potential to save lives in the field.

Google Glass – in addition to devices that sync with mobile phones, freestanding wearable technologies such as Google Glass are beginning to have a greater effect upon the way medicine is practised. Google Glass has been integrated into medical education and piloted in a busy Boston emergency department with great success.

The potential to use this technology successfully in disaster response is still being explored. As with mobile phones, Glass can use video conferencing to obtain triage and diagnostic support from remote healthcare providers and to document patient care as the patient eventually arrives at the hospital. Since they are 'glasses,' the person on the other end sees exactly what the user does and can guide them through procedures in the field or en route to the hospital. Moreover, the Glass's wearable design allows the user to keep both hands free to treat the patient and keeps the Glass from coming into contact with multiple surfaces like a phone or tablet would. Thus, Glass is a much more sanitary and easily applicable solution when performing procedures than other mobile devices.

Google Glass technology still remains in its infancy and is, at the time of publication, only available to Beta users. However, developers have begun to create healthcare applications with potential disaster response uses. For example, the University of California (UCLA) has developed an application that allows Glass to perform instant, wireless diagnostic testing for a wide range of diseases including HIV, malaria, TB, and syphilis in as little as eight seconds using rapid diagnostic testing strip technology. While this technology may seem like more of a non-emergent diagnostic tool, it is possible that strips can be developed to test for chemical poisoning or exposure.

Using Philips and Accenture's proof-of-concept demonstration using a Google Glass head-mounted display, a physician could monitor a patient's vital signs remotely or enlist assistance from doctors in other locations

Philips | Accenture

In addition to diagnostics, developers have created applications that enable users to treat patients. For instance, an application called CPRGLASS can guide rescuers through step-by-step CPR while contacting emergency medical services. Another complementary application called AED4.US allows Glass users to locate the nearest Automatic External Defibrillator in the event that a patient undergoes cardiac arrest.

Trauma care & transport

You have successfully completed the initial triage. You have found that 15 patients are in critical care condition, requiring ICU level care, and one patient requires emergent surgery. The rest of the patients require only basic level first aid care. In addition, volunteer staff on the ground need additional basic medical supplies and everyone needs more food and clean water.

The next step in the management of this situation depends on the scope of destruction caused by the disaster. If there is widespread damage, there may not be a hospital within a reasonable distance to which patients could be airlifted. Even if a hospital is nearby, healthcare providers may not be able to bring patients there, as the site may still be too dangerous. Scenarios such as this are commonplace in the military, but could also involve situations such as a nuclear reactor meltdown.

Life Support for Trauma and Transport (LSTAT) – one of the biggest challenges in disaster medicine is the treatment of patients who require an intensive level of care. In the 1990s, the Defence Research Projects Agency sponsored a collaborative project between Northrop Grumman and the Walter Reed Army Institute of Research (WRAIR) to develop the LSTAT system. The current version, sold by Integrated Medical Systems (a Northrop Grumman company), is an all-in-one portable solution for trauma treatment. It features a ventilator with on-board oxygen delivery, fluid/drug infusion, suction, defibrillator, blood chemistry analysis, patient physiologic monitoring, data logging with communications connectivity and power, and system data management. The system provides intensive care from the initial injury through transport to a high acuity medical centre with the potential to reduce morbidity and mortality.

ICU in a Can – the LSTAT system is quite useful for initial trauma care and transport, but patients in the field may also require long-term ICU care. If local infrastructure has been destroyed, medical providers will need to build or import additional structures. To this end, a designer named Kukli Han has developed a 'mobile hospital' system based on the overwhelming success of the Mobile Army Surgical Hospital (MASH) systems. The hospital comes 'packaged' in a shipping crate-like structure that unfolds into a multi unit field hospital equipped with examination rooms, inpatient hospital rooms, an x-ray facility, and even an operating room. Conveniently, the entire hospital can be moved by most common routes of transportation including ship, train, or helicopter, and can be customised with as many units as are needed to develop the capacity necessary for proper response. Currently, the project is still a concept but, if developed further, it has the potential to improve patient care greatly in these types of situations.

Drones – field hospitals cannot function without sufficient resources. Trucks and helicopters typically deliver medical supplies following disasters, but these methods prove problematic if the transportation infrastructure has been damaged. Furthermore, delivery by these methods can be incredibly slow and inefficient in large-scale disasters. A tailored approach to resource management may be far more effective in such situations.

Non-military use of drone technology is a recent phenomenon that has been used in various ways. In a disaster, drones could provide a portable and cost effective option for short distance use in life threatening situations and can enter dangerous situations without putting additional lives at risk. This could have huge implications for disaster response situations, particularly where traditional infrastructure has been destroyed.

Drones could be used to deliver medical supplies, food, lab tests, and other resources. Moreover, with new technology, they can be used to track heat signals to identify survivors, detect chemical levels, measure radiation, and survey the scenes for safety. As is the case with many of these technologies, drones are becoming less expensive to manufacture. In fact, engineers at Sheffield University in the UK have built a 3D-printed drone using roughly $9 (€6.70) worth of materials.

However, drones do have a major limitation – the amount of supplies that they are able to transport. For instance, the octocopter drones proposed for use by Amazon can only carry just over five kilos of supplies.

Dr David Feinstein, Assistant Professor of Anaesthesia at Harvard Medical School, tests out Google Glass before entering the Philips and Accenture OR simulator lab

Philips | Accenture

To overcome this obstacle, companies like Matternet are trying to develop large-scale drone infrastructure that can meet the capacity needs of traditional delivery services. Matternet has already carried out test runs in Haiti and the Dominican Republic, and plans to set up a drone infrastructure in Lesotho. Andreas

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Raptopoulos, CEO of Matternet, revealed in his TED talk that setting up a network in Lesotho, an area spanning 138km^2, will cost $900,000. This money will allow the company to build 150 vehicles and 50 stations. Upon completion of the network, the cost for each drone to carry a two-kilo load over 10km will be nominal.

Ideas such as Matternet's are based on the belief that one can use a large number of drones to deliver the same amount of supplies that a standard helicopter can transport, but with a more personalised and efficient approach. Furthermore, the utility of these products will improve continuously as the weight-bearing capacity of drone technology continues to increase. Political views aside, drones have the potential to truly affect the allocation and management of resources during disaster response.

As state-of-the-art technology is widely adopted in many fields of medicine, the time has come to integrate such technologies into disaster medicine further. Innovative measures on how to apply easily accessible technology can lead not only to sophisticated and highly efficient services that can enhance healthcare delivery, but may also further improve survival outcomes. As medicine is always evolving, it is crucial for disaster medicine to apply technology not as an exception, but as a necessity. GIS, mobiles, tablets, and other such devices are widely utilised in many medical specialities. Disaster medicine should be at the forefront of this utilisation as space and information technology is now so readily available that not applying it to healthcare services in a disaster situation is definitely a disadvantage to both healthcare providers and patients. CRJ

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