"Beacons of Hope" in Decentralized Coordination: Learning from On-the-Ground Medical Twitterers During the 2010 Haiti Earthquake

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ABSTRACT

We examine the public, social media communications of 110 emergency medical response teams and organizations in the immediate aftermath of the January 12, 2010 Haiti earthquake. We found the teams through an inductive analysis of Twitter communications acquired over the three-week emergency period from 89,114 Twitterers. We then analyzed the teams' Twitter streams, as well as all digital media they generated and pointed to in their streams—blog posts, photographs, videos, status updates and field reports—to understand the medical coordination challenges they faced from pre-deployment readiness to on-the-ground action. Here we identify opportunities for improving coordination in a decentralized and distributed environment where staffing, disease trajectories, and other circumstances rapidly change. We extrapolate from these findings to theorize about how "beaconing" behavior is a sign of latent potential for coordination upon which mechanisms of coordination can capitalize.

Author Keywords

Computer-mediated communication; crisis informatics; disasters; field medicine; microblogging; social media.

ACM Classification Keywords

H.5.3 Groups & Organization Interfaces—collaborative computing, computer-supported cooperative work; K.4.2 Social Issues.

General Terms

Design; Human Factors.

INTRODUCTION

Age-old arguments continue about whether decentralization or centralization of functions is the optimal way for organizations to work and their members to cooperate, with fluctuations between these configurations marking each new age in modern business [2,5,14]. In disasters, however, there are no such options. For nearly all of its functions, disaster response is an inherently decentralized and distributed institution that is under continuous and unexpected change [28]. The more dramatic the catastrophe and the more difficult it is to converge onto a location, the more decentralized the response. Helpers new to disaster response—and there are always many of these—will ask, "Who is in charge?" and be shocked by the answer [17]. Coordination problems are prolific, with matters of medical response being especially critical because of the immediacy of needs [4,22,28]. The decentralization that characterizes field medicine results in a surplus of personnel in one area and a dearth in another, with loss of life as the consequence.

In the world of disaster management, the rise of social media has opened the space for aid organizations as well as members of the public to participate in generating, filtering and sharing real-time information during times of crisis [6,21,24,30]. A line of research inquiry as well as a line of methodological opportunity arise from such conditions, both of which we undertake in this paper. For the first—the line of research inquiry—we ask: What prospects and problems do social media create for the inherently decentralized coordination in disaster response? Unlike coordination of safety-critical systems, which is co-located and centralized [1,10], what are the features of decentralized work that need technological support? How are social media shaping that landscape of possibility now?

For the second, we aim to leverage the methodological opportunity that social media data provide for near real-time, situated, and often first-person accounts of events on the ground—situations for which field work would be limited and even at odds with the foremost aims of offering direct assistance. With the advent of social media use during post-impact disaster situations—even under the dire conditions of an event like the 2010 Haiti earthquake, the infrastructure was stabilized such that web access and social media use was possible by those who had the required hardware—we no longer need to rely on traditional post hoc written accounts of disaster field experience alone to obtain a rich accounting of the circumstances.

In short, this paper aims to study a large-scale, fast-paced, and stressful coordination activity that is highly distributed and decentralized—medical coordination during disaster response. We extend the methods of virtual ethnography [11] by systematically mining a comprehensive set of Haiti-related social media data to investigate the 2010 Haiti earthquake emergency medical response.

MEDICAL SITUATION AFTER THE HAITI EARTHQUAKE

On January 12, 2010, a massive earthquake struck Haiti near the city of Leogane, about 18 miles west of the capital Port-au-Prince. The severity and scope of impact of the earthquake was catastrophic. The Haitian government estimated that more than 222,000 people lost their lives and over 300,000 were injured [19]. The immediate medical needs were immense, requiring acute trauma care, orthopedic services and access to life-saving medications and equipment. The most common injuries included open and closed bone fractures, bone dislocations, complex open wounds, and head, face, and brain injuries. As one of the physicians noted in his dispatch from the field, "A city in need of hundreds of trauma centers had two or three" [20].

The earthquake damaged or destroyed much of the Haitian medical infrastructure, disrupting the healthcare system when it was most needed. Of the existing 49 hospitals, eight were totally destroyed, and 22 seriously damaged [19]. Those that remained functional were crowded with patients, forcing many people to be treated in temporary structures, such as inflatable hospitals and makeshift facilities. Many of the local healthcare workers were also killed or injured, or had lost family members. Medical facilities lacked essential medical staff, supplies, equipment and drugs.

A large-scale humanitarian response was launched in the immediate aftermath of the earthquake, with Pan American Health Organization and World Health Organization (PAHO/WHO) forming the Health Cluster (within the United Nations Cluster system) and leading the emergency medical response. Responsibilities of the Health Cluster included outlining medical relief priorities and coordinating support offered by over 400 health partners, non-governmental organizations (NGOs), and emergency relief agencies. According to PAHO/WHO reports, many of the responding agencies had no prior experience with Haiti, disasters, or the Health Cluster system [19].

Emergency medical response included rapid establishment of 17 field hospitals in the most devastated areas, two ship-based hospitals with hundreds of medical specialists and large capacities, distribution of emergency medical supplies, and provision of essential medications and medical equipment. Over 150 nations provided support by sending emergency medicine specialists, trauma and orthopedic surgeons, nurses and other medical personnel [9]. Humanitarian and medical aid agencies supplied food, water, hygiene kits, medical equipment and medications such as antibiotics, vaccines and anesthetics [19].

The Health Cluster, in collaboration with several other partners, established a Health Information Situation Room as the basis for coordinating medical response and collecting and managing health information. The goal was to have an overview of the needs, epidemic trends and services available on the ground [19]. Despite these efforts, emergency medical teams and organizations that responded to the earthquake faced great challenges in preparing for and providing medical care. Several physicians on the ground described the initial response as "ill-equipped, understaffed, poorly coordinated and delayed" [17]. Additionally, logistics of medical response were hampered by the destruction of infrastructure and transportation [31]. Importantly, telecommunications infrastructure was mostly restored to a workable degree. Though high rates of phone calls sometimes taxed the system, those on the ground who had access to data services could make use of them, including the use of microblogging services [8].

METHODS

To navigate the enormous social media-based information space and the online sources to which the social media communications pointed, we took Twitter communications as a starting point. Twitter is a popular microblogging platform that allows users to send 140 character messages to their followers, also captured in the public stream. In addition to reading posts, or "tweets," from their followers, people can search the public stream for keywords that would reveal topics of interest. As we know from prior research, tweet communications, which are increasingly used by professional groups and volunteers in disaster response, often contain pointers to other sources on the web [24]. By isolating "medical Twitterers" on the basis of words contained in their tweets—a significant methodological challenge on its own—we hypothesized that we would be pointed to other relevant online sources that could also be used for ethnographic investigation.

Immediately after the earthquake struck in Haiti, we started collecting tweets via Twitter's Search API using the keywords *earthquake*, *Port-au-Prince*, *Ouest*, *tsunami*, *Haiti*, and *tremblement*. Over the period of January 12 – March 10, 2010, the search generated 3.28M tweets contributed by 799,955 Twitter users. Our goal to identify medical tweets and on-the-ground Twitterers from this large dataset posed significant challenges, leading to a three-step process: (1) identifying tweets with medical information; (2) generating a sample of high-volume medical Twitterers and using the information in their tweets to identify emergency medical responders who tweeted from the ground; and (3) capturing Twitter streams of identified on-the-ground medical responders for further analysis. The detailed process is summarized in Figure 1.

Identification of Medical Tweets

Although the Government of Haiti called off the official search and rescue on January 23, 2010, some rescue efforts continued for another week [29]. We limited our collection
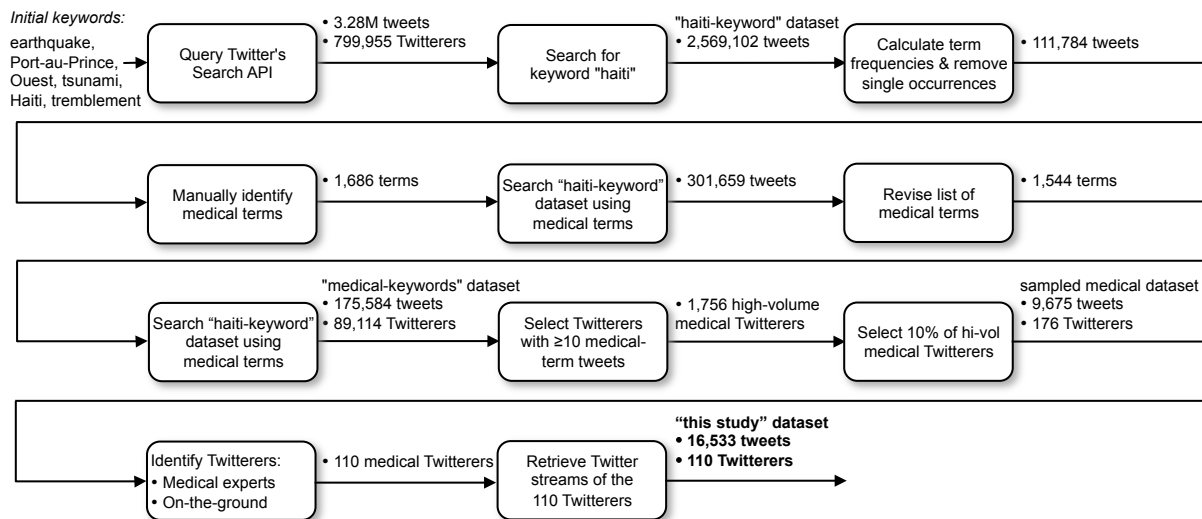
Figure 1. Summary of the procedures used to identify medical tweets and to reach the sample of 110 Twitterers.

of Twitter data to the three-week period—from January 12 to February 2, 2010. Using the 3.28M dataset, we selected all tweets that contained the term "haiti," which yielded 2,569,102 tweets (the *haiti-keyword* dataset). We then computed term-frequency counts for all words, including their misspellings and shortenings. We also removed links, email addresses, numbers, single letters, and punctuation and symbols, except hyphens and apostrophes. This process generated 211,047 terms, of which 99,263 occurred only once. Because single-occurrence terms carried little weight (e.g., they were not retweeted), they were excluded from analysis. This process yielded a list of 111,784 terms.

Two researchers, one with experience in ethnographic research on emergency medicine, manually reviewed the list and identified medical terms. Medical terms were defined as those that relate to medical conditions, interventions, treatments, professions, equipment, instruments, and supplies; medical institutions and healthcare companies; emergency response agencies and organizations; emergency medical transportation, public health issues, and anatomical parts. This broad search for medical terms resulted in 1,686 terms and 301,659 tweets. Through several iterations of the medical-terms list and analysis of the tweets retrieved by those terms, we converged on 1,544 terms that we hypothesized, based on experience with this dataset, would return authentic medical tweets. Using these terms, we again searched the haiti-keyword dataset, yielding 175,584 tweets that contained ≥1 authentic medical term (the *medical-keywords* dataset). Of these, 140,540 (80%) contained a URL or one of the common retweet conventions (RT @ or via @).

Identification of Medical Twitterers on the Ground

The medical-keywords dataset consisted of 89,114 Twitterers. We were specifically interested in identifying those on the ground to understand geographically constrained coordination. We used additional criteria to narrow the focus to either medical professionals or those

affiliated with medical or aid organizations on the ground, including: 1) academic medical centers or hospitals from abroad that dispatched a field team; 2) temporary field hospitals or medical facilities on the ground; 3) medical aid or humanitarian organizations; 4) charitable or faith-based organizations specialized in providing healthcare; or 5) individuals with medical background and affiliated with a medical group on the ground.

To identify Twitterers who met this criteria, we selected a random sample of 10% who sent ≥10 tweets, resulting in 1,756 high-volume medical Twitterers. Because the volume of tweets per user falls in a heavy-tailed distribution [16], we applied a tweet-based, rather than Twitterer-based, sampling strategy. We randomly selected tweets from the medical-keywords dataset and then selected authors of those tweets, continuing the procedure until we reached a 10% (176) sample of high-volume Twitterers.

Next, we examined the tweets from the medical-keywords dataset of 176 high-volume users to identify on-the-ground medical responders. We studied the social networks for all Twitterers who were named or referenced in those tweets. This manual search required reading all the tweets for each high-volume user, identifying all the @*<name>* mentions, and investigating who the mentioned person is by reading their streams and exploring their Twitter profiles and personal or organizational websites. For most users, we were able to determine the deployment dates and locations based on the content of their tweets. Some users stated explicitly on their personal websites if they were in Haiti during the emergency response. The tweets also indicated if the user was a remote proxy tweeting on behalf of their medical team on the ground (e.g., "*Heard from David. Team is in the Dominican and will be heading to Haiti at 1:00am.*"). Once we reached the point of diminishing returns, meaning that we were not identifying new on-the-ground medical Twitterers, we stopped the search.

Medical Twitterer Category	%	Medical Twitterers
Academic medical centers and hospitals from abroad	5%	@BHWSurgery, @CRUDEM_Haiti, @emoryhealthsci, @HopkinsMedNews, @MeridianNJ, @paloaltomedical
Field hospitals	5%	@BHMhaiti, @CVN70, @IDFinHaiti, @IDFspokesperson, @USNSComfort
Medical aid and humanitarian organizations	49%	@AAOS1, @AmeriCares, @ARCrelief, @Britishredcross, @CARE, @compassion, @crsnews, @directrelief, @enochchoi, @erlangerhealth, @federation, @HHI, @HHSGov, @HopeForHaitiFL, @icrcnews, @IMC_Worldwide, @ISOHIMPACT, @itsChance, @Medishare4Haiti, @medshare, @medteams, @merlinUK, @merlinUSA, @moarctha, @MSFAustralia, @MSF_canada, @msf_field, @MSF_ireland, @MSF_uk, @MSF_USA, @NavyMedicine, @NavyNews, @nphi, @operationbless, @oxfamamerica, @pahoeoc, @pahowho, @PIH_org, @projecthopeorg, @RedCross, @redcrosscanada, @savethechildren, @SSMHealthcare, @SurgeonsSOS, @TeamRubicon, @UNICEFLive, @unicefusa, @US_Air_Force, @usafpressdesk, @USAID_Haiti, @usaid_news, @uscoastguard, @USMC, @whonews
Charity and faith-based organizations	13%	@G2missions, @haitihospitalap, @hcjbglobal, @LWCmissions, @MeandMyHouse, @MercyShips, @missionMANNA, @mohhaiti, @One5Foundation, @operationsmile, @Rockers4relief, @SAScharity, @SamaritansPurse, @thegreeneteam
Individuals affiliated with medical centers, teams or organizations	28%	@AlexforMerlin, @aokeke, @avrilbenoit, @bfrist, @blakecanterbury, @CarlosMiranda, @conneally, @craigkielburger, @DokteCoffee, @DrJimSears, @drval, @evanlyon, @francoordonez, @ijeanson, @johnpbuckner, @jonmartinlarsen, @lightxxx, @LucasCCarlson, @MartineATF, @melindayiti @MerlinChiefExec, @minhnguyenMD, @nateloucks, @nursetim, @Rich_UNICEFUSA, @rickperera, @shollingworth, @SanjayGuptaCNN, @spencenix, @TheDoctors, @troylivesay

Table 1. 110 medical Twitterers and their distribution across five categories. Italicized users represent remote proxies.

The result of this extensive analytical search was 110 found medical Twitterers who produced 16,533 tweets, a list that we believed was representative of major medical players on the ground (Table 1). Among these, 62 (56%) users represent remote proxies who tweeted on behalf of their medical teams on the ground (italicized users in Table 1). 21 (19%) users joined Twitter in the January 12-24, 2010 timeframe. Most of the new Twitterers were small NGOs, field hospitals and their affiliates.

Data Analysis: Extension to the CMC Information Space
Using Twitter's REST API, we obtained the entire Twitter streams for the three-week emergency period for 102 of the medical Twitterers. For the remaining eight, we used tweets from the medical-keywords dataset as their accounts had since closed.

As we hypothesized, Twitter streams pointed to other digital media that were published and broadcast through different computer-mediated communication (CMC) channels. A total of 6,210 (37%) tweets contained URLs, most of which led to official website communications, online field reports, blog posts, videos, Facebook posts, and photographs posted on sites such as Flickr or Twitpic (Table 2). We excluded news media reports because they do not necessarily contain first-hand information. Twitter streams of medical centers and physicians also pointed to their "dispatches from the field" and post hoc accounts published in medical journals. Two researchers on our team performed content analysis of this large information space using a dedicated room to display, examine and cross-reference data points across these many media. Over the period of two months, we inductively analyzed the data collected from Twitter and other CMC channels to identify themes related to coordination challenges and information sharing during the emergency response period.

To better understand the prospects and problems that social media create for the decentralized coordination in disaster response, we also analyzed social network graphs of the 110 medical Twitterers. Using their Twitter streams, we examined how they formed online relationships, whom they interacted with and whom they followed. To answer these questions, we identified the top 25 accounts that had the most mentions and retweets in our dataset. We also identified the accounts that our users mentioned or retweeted individually. Finally, we looked for the mechanisms by which medical Twitterers suggested other users to their followers.

EMERGENCY MEDICINE COORDINATION
We first describe the medical work coordination and use of social media during the preparation phase, followed by a description of coordination during field deployment.

Medical Coordination During the Preparation Phase
Our data analysis, complemented by the data from post hoc accounts published in medical journals, revealed three types of emergency medical responders to the Haiti earthquake based on their prior disaster experience and response time.

First, rapid deployment of emergency medical teams was accomplished by organizations with extensive experience in mass casualty response, such as military, disaster management agencies, government-sponsored organizations and other crisis-oriented entities. For example, the U.S.

Media Type	Number of Medical Twitterers
Photographs	93 (85%)
Websites	85 (77%)
Blogs	72 (65%)
Videos	69 (63%)
Facebook	65 (59%)

Table 2. Distribution of media use by type across medical Twitterers.

Navy aircraft carrier, USS Carl Vinson (@CVN70), arrived off Haiti on January 15. The Israeli Defense Forces Medical Corps field hospital (@IDFinHaiti), capable of providing sophisticated medical care, was fully operational on site only 89 hours after the earthquake struck [15].

Second, collaborative initiatives formed by U.S. medical centers, such as Project Medishare (@Medishare 4Haiti) [7] were also able to respond rapidly due to their preexisting relationships with established NGOs on the ground. Institutions worked with the implementing agencies on the ground to compose teams, create lists of medical supplies and equipment, and develop strategic plans.

Finally, those without preexisting relationships with NGOs on the ground or preexisting international disaster programs (e.g., ad hoc academic medical teams and self-deployed volunteers) responded later, faced significant preparation challenges, and were ill-prepared for the conditions on the ground [18]. As reported by physicians on the ground [17, 31], many donor countries sent emergency medicine teams to build field hospitals, but not all of them came prepared.

Two main coordination challenges emerged in the pre-deployment readiness based on the social media data and post hoc accounts: 1) information from partners on the ground was often incomplete and sporadic, and 2) needs on the ground changed throughout the response. Our analysis elaborated on these challenges and showed that social media were used not only for broadcasting information needs, but also for providing needed information.

Preparing for Conditions Based on Incomplete Information
Incomplete and sporadically available information about the conditions on the ground required preparation for a more universal medical response. For example, the location of team deployment and the actual team assignments were often not known until shortly before departure [18]. A team's preparation and needs assessment for necessary equipment and supplies were therefore in continuous flux.

Social media data showed that all three types of medical responders faced this problem. NGOs and individuals outside Haiti who organized teams of doctors for deployment requested information about site locations from those who were on the ground, regardless of whether or not they had previously established relationships. Consider for example a tweet directed by a leader of an NGO to Partners in Health (PIH), a non-profit organization:

```
@PIH_org this is Melinda Miles, I've worked with
PIH a lot and I have surgeons ready to go to
Haiti, who should I call?
(@melindayiti, Jan 16, 2010)
```

Larger medical and humanitarian aid organizations with an established presence in Haiti either contacted their staff on the ground or dispatched assessment teams immediately after the earthquake struck to obtain information on the most urgent needs. For example, Doctors Without Borders/Médecins Sans Frontières (MSF) had operated three medical facilities in Haiti since 1991 and had 800 medical staff on the ground. Although these facilities were badly damaged in the earthquake and many of the staff were injured, a few staff members were able to quickly assess the situation and share information through Twitter, Facebook and field reports posted on their website. Below is an excerpt from their January 13 field report:

"One of MSF's senior staff, [name], was out for most of the night, trying to assess the needs in the city and looking at the state of the medical facilities. 'The situation is chaotic,' he said. 'I visited five medical centers, including a major hospital, and most of them were not functioning.'"

We observed many instances of individuals and organizations that responded immediately and operated at different locations on the ground using social media to disseminate information about needed medications, equipment and supplies. For example, @MartineATF, a self-deployed volunteer working at the Baptist Haiti Mission hospital (@BHMhaiti) in Port-au-Prince tweeted:

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I've created a list of medical supplies in need
at BHM Hospital: @ me your email if you'd like me
to forward. (@MartineATF, Jan 16, 2010)
```

Similarly, International Medical Corps used both Twitter and Facebook to disseminate information about their needs:

```
Don't have enough of some basic wound care
supplies, nurses and those with basic first aid
experience. (@IMC_Worldwide, Jan 17, 2010)
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These tweets and other social media posts contained important and useful information for those who were preparing for the deployment. Yet, publicly available social media communications do not provide any evidence that medical teams used such posts as an information source for their preparation. As reported in post hoc accounts, medical teams mostly relied on telephone and email to coordinate preparations [18]. After all, the above tweet from @MartineATF calls for email use as a means of communicating additional details. We observed, however, that social media like Twitter played a role in reaching potential helpers and providing contact information. As the above examples illustrate, most tweets from on-the-ground medical Twitterers were not directly addressed to anyone, nor were they passed on by these Twitterers from another source. Indeed, the 48 medical responders who tweeted from the ground produced a total 4,877 tweets, of which 3,335 (68%) contained no language indicating retweets or direct addressing to others (RT @, via @, or @<name>), with 27 of these Twitterers producing more than 75% of their tweets without addressing or redirection. Medical teams on the ground appeared to use social media to express their needs and report status, often without knowing who might be reading their messages or following their Twitter streams. We call this behavior *beaconing* to describe the regularly sent signals of information broadcast to the Twitterverse at large. As we explain later in the paper, beaconing is a precursor to coordination in a highly decentralized work environment.

Investigation of the teams' deployment dates and their Twitter interactions also revealed that relationships among some medical teams started to form *after* they deployed. We identified several clusters of medical responders who communicated with each other via Twitter during their deployment. To establish connections, teams made recommendations by relying on the #followfriday or #FF norm, by sending targeted follow requests, or simply by "recommending" accounts they trusted. For example, one such cluster formed among charity-based organizations, including @SamaritansPurse, @hcjbglobal, @MeandMy House and @ISOHIMPACT, whose medical teams deployed to the Baptist Haiti Mission hospital (@BHMhaiti). They connected with each other upon their arrival to Haiti, after @BHMHaiti sent a targeted request:

```
@MeandMyHouse @hcjbglobal Can you follow us so we
can send direct msgs? Thnx!"
(@BHMHaiti, Jan 18, 2010)
```

Based upon these findings, we hypothesize that medical teams did not use social media as an information source or even as a coordination mechanism during the pre-deployment readiness phase because they were not aware of streams or Twitterers on the ground who had the information they needed. In contrast, teams that were on the ground and in need of medical supplies and personnel did use social media to disseminate information about their needs, but did so broadly without directly addressing particular groups or individuals, hoping that someone would respond— this is, again, beaconing behavior.

We also noted that organizations—both large and small—and medical teams on the ground frequently posted photographs of medical facilities and physicians in action. In these photographs, one can see the severity of damage to the building or care facility, medical equipment in use, patient injuries, geographic location of the site, and even weather conditions. There is no explicit evidence that such photos were used for tactical planning. However, the availability of them in disaster response is a tremendous planning resource, if they could be readily available, consolidated and geo- and temporally-located.

Preparing for Conditions under Continuous Change

Medical needs were not only unknown, but were also changing on a daily and then weekly basis. This problem was most evident with medical personnel needs. In the immediate aftermath of the earthquake, the biggest demand was for orthopedic and trauma surgeons due to the traumatic nature of injuries sustained by victims. Many tweets and other online content reflected this need:

```
Haiti needs surgeons so I am going at 3 tomorrow-
desperate need for antibiotics, need in bulk
only-if you have extra: http://bit.ly/7bPOUh
(@bfrist, Jan 16, 2010, note: link is broken)

attention: no neurosurgeons in haiti that can be
found. needed, along with proper instruments.
please ensure uss comfort has one as well.
(@SanjayGuptaCNN, Jan 18, 2010)
```

Urgent demands for surgical care were also reflected through posts on the number of surgeries that field hospitals carried out daily. For example:

```
Update from #Haiti: We believe that 1,500
patients are inside and outside the hospital.
Approximately 70 to 80 percent need surgery.
(@IMC_Worldwide, Jan 17, 2010)

Doctors Without Borders surgical teams have been
carrying out an average of 130 operations/day in
#Haiti. http://bit.ly/5su7sF
(@MSF_USA, Jan 21, 2010)
```

A blog post from the Sutter Health medical team (@paloaltomedical) posted on January 25 further illustrates the need for acute surgical care:

"The Sutter Health team continues to treat patients and perform surgeries at St. Nicholas Hospital in St. Marc – working an average of 20 hours a day. Above [photo] Stephen Lockhart M.D., anesthesiologist and chief medical officer for Sutter Health's East Bay Region stands by the list of patients awaiting surgery. At 4:30 p.m. (Haiti time) there are 17 patients who still need treatment today."

About two weeks into the emergency response, calls for personnel needs shifted from surgeons to other medical specialists. Once the first wave of critically injured patients passed, a larger need for post-operative care specialists and rehabilitation medicine physicians emerged. In addition, less critically injured patients and those with chronic diseases started to seek help. Infectious diseases (ID) started to spread as well, resulting in a new call for ID physicians. This shift in personnel needs was also reflected through social media posts. Consider for example a tweet from @ISOHIMPACT, a charitable organization specializing in medical intervention and disaster relief:

```
Thinking of coming to Haiti? There will be a real
need for rehab medicine docs in ~1 month when
wounds healed and prosthetics available.
(@ISOHIMPACT, Jan 21, 2010)
```

On January 28, @IMC_Worldwide, the International Medical Corps, posted to their Facebook wall:

"noticed a dramatic change over the past 48 hours in the type of patients they [the doctors] are seeing. Instead of treating a constant stream of severe and urgent earthquake-related injuries, there are now patients coming to the hospital with less urgent medical needs, such as high blood pressure or minor skin growths."

Others provided similar status updates via Twitter:

```
Doctors Without Borders is now treating more
patients for pre-existing conditions & infections
in #Haiti http://bit.ly/4GffTl
(@MSF_USA, Jan 24, 2010)

Medical orgs in Haiti say surgical needs are
lessening & there will be greater need for
management of infections & mental health care.
(@HHI, Jan 27, 2010)
```

Several medical teams and individuals on the ground cautioned that even though surgical needs were lessening, there was still an overall demand for surgeons, especially in

rural areas. In addition, many patients were being readmitted due to wound infections caused by inadequate initial care, requiring surgeries to be redone. Tweets below illustrate this continuous demand for surgical care:

> Seeing a lot of patients with amputations that were done poorly a week ago by other hospitals with no follow up — many needing to be redone. (**@troylivesay, Jan 23, 2010**)

> There is still a need for docs and nurses in Haiti. I hope people keep coming. #Haiti (**@DokteCoffee, Jan 29, 2010**)

The shift in personnel needs affected not only those who were preparing for deployment, but also those who were already on the ground. @MissionMANNA, a non-profit organization providing medical care for malnourished children, reported via Twitter on January 29:

> #Haiti #avlnews numerous teams of medics, nurses, doctors, surgeons waiting in frustration outside hospital, wanting desperately 2 be useful (**@MissionMANNA, Jan 29, 2010**)

Sanjay Gupta, a neurosurgeon and medical correspondent for CNN, who was actively involved in providing medical care, blogged about a similar situation on January 25:

> *"...after a few days of limited help, there is now such a surge of surgeons, some medical personnel are being turned away from some of the big hospitals in Port-au-Prince. 'We appreciate your efforts, but we have more surgeons than we need,' is being repeated at the general hospital in downtown."*

That some medical teams were still expressing the need for surgical care while others talked about a surplus of surgeons confirms the lack of coordination and information exchange among medical teams, but also demonstrates an opportunity for social media and other forms of ICT to aid in supporting the decentralized work conditions on the ground. Although medical teams expressed their needs and concerns through social media, there is no evidence in our data that they used social media for direct communications and coordination as they prepared for deployment.

Medical Coordination During the Deployment Phase
Upon their arrival, medical teams and groups faced different kinds of coordination challenges. One of the main problems often cited in post hoc accounts included the lack of organization on the ground [9, 31]. As several physicians reported from the field, "Doctors were coming to Haiti with no plan of what they were going to do and they received limited help and directions once they arrived" [17].

All disaster situations have spontaneous volunteers who converge onto the geographical arena [13]. It is also common for specialized groups to self-deploy, including engineering and medical teams, even if they have no prior disaster field experience [28]. In the 2010 Haiti earthquake disaster, emergency physicians and teams from university hospitals with experience in acute trauma care volunteered both their personal and institutional time to help a region in need. However, not all had disaster experience and were

unprepared for the lack of coordination that characterizes disaster situations. These teams and NGOs that were coordinating their deployment often used social media to express concerns about the lack of centralized coordination. Consider a tweet from @melindayiti, a leader of the NGO called "Working together for Haiti":

> Who is in charge of the response in Haiti? Where is the national strategy? (**@melindayiti, Jan 16, 2010**)

In contrast, teams and NGOs with more experience seemed to understand the reality of large-scale disasters and knew how to organize their activities:

> Aid effort undeniably slower than we would want but the reality is what it is. No infrastructure. Little central control (govn. in a tent). (**@conneally from Red Cross, Jan 17, 2010**)

> In CARE's nightly coordination mtg, where team is planning logistics, trucks, locations for tomorrow's aid -- like a well-oiled machine! (**@rickperera from CARE, Jan 23, 2010**)

We next describe three main coordination challenges in the deployment phase—coordination among hospitals, patient coordination, and medical supply coordination—and how these challenges materialized through social media.

Coordination among Hospitals on the Ground
Teams working in field hospitals reported difficulties in obtaining information about other field hospitals and makeshift facilities, and expressed the need for hourly updates on their capacities and capabilities [20]. As @lightxxx, a volunteer on a medical mission, reports:

> Another thing there are no communications between the hospitals # Haiti (**@lightxxx, Jan 24, 2010**)

Information about hospital capacities was needed for managing patient distribution, especially for patients needing specialized care. Analysis revealed that some field hospitals posted their status in real-time. Consider this Facebook post on January 17 by @CRUDEM_Haiti, the largest private hospital in North Haiti:

> *"A load of 6 patients was due to arrive yesterday evening but unfortunately on route the pilot was forced to turn back because of the terrible weather conditions. Our general surgery team arrived yesterday, an orthopedic team today. We need the patients to be brought to us in much greater numbers!!"*

Or a tweet from the CARE organization, whose medical team operated in one of the hospitals in Port-au-Prince:

> Hospital in Port-au-Prince #Haiti are full of severely injured individuals; no room to accept add'l wounded. (**@CARE, Jan 14, 2010**)

Here, too, we noticed medical teams exhibiting beaconing behavior—reporting their status and posting requests in hopes that someone would respond. During the preparation phase, no responses to such messages were discovered in the analysis. However, responses to these requests were found to have occurred during the deployment phase. Interestingly, rather than coming from other medical

responders on the ground, responses mostly came from digital volunteers, or "remote operators" of various backgrounds who were moving information between sources both on and off the ground, and were contributing to resolving the expressed problems [26]. Our analysis of social networks showed that many medical teams on the ground mentioned the following digital volunteers: @ShaunKing, @MelyMello, @SuziLeVeaux, @thehaitian, @Crimson_Cougar, @kiskeacity, @lorihcg, @VRWC Texan, and others. For instance, @mohhaiti, a non-profit Christian organization based in Port-au-Prince, posted an urgent need for food for their medical facility and almost immediately received help from several remote operators.

Patient Coordination and Transportation
Many patients required medical evacuation to the ship-based hospitals off the Haiti shore, while some patients required evacuation to hospitals in the U.S. Damaged infrastructure and scarce resources imposed multiple constraints on coordinating patient transfer.

In addition to using social media to express frustrations or discuss coordination problems, a few medical teams saw social media as a potential place for action and used it to coordinate patient care during their deployment. An instance comes from the IDF field hospital (@IDFinHaiti). On January 22, IDF doctors diagnosed a 4-year old Haitian with leukemia who needed urgent transfer to a U.S. hospital. @IDFinHaiti called for help via Twitter and blog:

```
mike, 4, diagnosed w stage 5 leukemia 2day,
trying to get him to US for treatment ASAP,
ideas: idfinhaiti@gmail.com
(@IDFinHaiti, Jan 22, 2010)
```
```
Mike, 4, stg 5 leukemia, we need someone to get
him to the US for immediate care:
http://is.gd/6OWBd (@IDFinHaiti, Jan 22, 2010)
```

After 4.5 hours, their Twitter post announced that the patient was successfully transferred:

```
Mike, 4, diagnosed with leukemia is being brought
to Univ Miami Hosp for treatment by org 'God's
Planet'! (@IDFinHaiti, Jan 22, 2010)
```

Our data do not show any digital traces of the means by which this help was obtained; this likely happened privately via email, as indicated above. Nevertheless, we found a quote on IDF's blog that refers to "an overwhelming response" to their tweet, which in turn shows the promise of social media in supporting information exchange and work coordination during emergency medical response.

Medical Supplies Coordination
Obtaining essential supplies was difficult; medical teams complained about the overwhelming bureaucracy and delays in supply distribution. Reports via social media described supplies standing still on the tarmac:

```
Witnessed all of the supplies stockpiled in the
airport. So well protected that nothing gets out.
Sad to see. #Haiti (@ISOHIMPACT, Jan 26, 2010)
```

Problems were also reported with getting supplies to Haiti. The airport in Port-au-Prince reopened on January 13, with

U.S. Airmen controlling the airport traffic. As reported on the U.S. Air Force website, the capacity was exceeded by more than 100 percent, increasing from 50 to 140 flights per day. Many planes wanted to land and many planes needed to depart because of evacuations.

Doctors Without Borders were incredulous that they could not land their planes with medical supplies and demanded the U.S. Air Force allow them to land, which created tensions and media outcry. Many MSF's tweets, field reports and blog posts discussed this problem:

```
Total 5 #MSF planes w 85tonnes medical/relief
supplies diverted from PaP to Dom.Rep. since Jan
14 http://bit.ly/7xheyT
(@MSF_canada, Jan 19, 2010)
```

"According to Dr. Greg Elder, deputy operations manager for MSF in Haiti, some sites are facing a 10 to 12 day backlog of patients due to the huge number of people who need treatment and ongoing delays in getting supplies into the country. Some victims are already dying of sepsis, an illness caused by infections that can affect people with untreated wounds." (Jan 20, 2010)

Twitterers around the world who followed the medical situation in Haiti massively retweeted MSF's complaints and directed them to the U.S. Air Force. In one of MSF's tweets, we see a positive outcome of such actions:

```
Thanks for your RT's to the USAF — u helped land
our diverted cargo plane in #Haiti yesterday!
Good work everyone :) http://bit.ly/4Hhky6
(@MSF_canada, Jan 18, 2010)
```

Additionally, we observed a few instances of direct communications via Twitter between teams on the ground to coordinate medical supplies and equipment. As an example, @ISOHIMPACT expressed the need for a portable x-ray machine for one of their hospitals and @IDFinHaiti responded positively:

```
Double Harvest (doubleharvest.org) has a real
need for an X-ray machine. We are trying to find
one stateside. Any ideas? Contact ISOH #Haiti
(@ISOHIMPACT, Jan 20, 2010)
```
```
@VRWCTexan @isohimpact indeed we have a portable
digital xray machine (@IDFinHaiti, Jan 20, 2010)
```
```
Looks like we have a port X-ray to pick up for
hospital at Double Harvest. THANK YOU @IDFinHaiti
and all who helped w this! #Haiti
(@ISOHIMPACT, Jan 20, 2010)
```

Though some communications between medical responders on the ground did occur, it seemed that remote operators (@VRWCTexan in the above case) played a critical role in establishing connections between the seekers and providers.

CONCLUSION
The nature of medical work in disaster response is a highly distributed and decentralized work activity, often ill-coordinated by virtue of the nature of the event itself. We have organized the discussion of coordination in this paper around coordination during preparation and field deployment, because much of a team's capacity on the ground rests on the appropriateness of the equipment and

personnel they bring, advance knowledge of the circumstances of their deployment location, and advance knowledge of current medical needs on the ground.

Social Media and Coordination: Reality and Potential

Social media data as well as accounts in the published literature showed that pre-deployment preparation was hampered by teams not knowing the conditions they were about to face. We saw little evidence of social media being used for pre-deployment coordination. However, it is here where we saw the first round of opportunities for rapid and more comprehensive preparation through a network of those already on the ground or in a state of pre-deployment. Coordination among teams during preparation is important because of their potential to optimize resources and deployment sites while they still have flexibility to do so.

Once on the ground, the teams continued to perform their work under decentralized conditions, which was in part characterized by disparities between their capacities and the kind and number of patients who sought their services. In some cases, we saw too high a demand placed on medical teams and in other cases, too little. Uneven distribution of patient load is not uncommon in disasters, but this is a critical area of opportunity not only for optimal mobilization of patients but also for the optimal placement of field teams. A major lesson here is that if decentralization is the manner in which work is conducted, as it almost always will be in disasters, then offering decentralized solutions, which allow teams as a population to self-organize, is the best direction to take. Social media and other forms of ICT are a natural place to enable such decentralized coordination.

Beaconing Behavior as a Precursor to Coordination

The role of social media in the work of medical teams varied and, in general, had little use in the way of regular cross-collaboration. Naturally, one would expect that busy medical teams have little time to tweet or blog. Yet, we know that at least 110 medically-oriented groups *did* use social media to report on their on-the-ground relief efforts. It is from *how* they used social media that we can infer more about their situation, expand the potential for social media, and identify a new social media-abetted behavior that is characteristic of large-scale decentralized tasks.

Of the medical Twitterers we identified, it was the smaller organizations and NGOs that tweeted regularly, but without addressing a particular person. Furthermore, when they included URLs, those links led to identical content but posted in a different media, e.g., Facebook or website. The tweets provided valuable information about the teams' situation but were simply broadcasts, without specific interaction with others. This is what we call *beaconing behavior*. Beaconing suggests an intention to be heard and a desire to be found. It happens when Twitterers (in this case) do not know to whom to direct their communications. It happens when there are not enough resources to put into navigating the social media space to find people who can

help. In a world where social media are a means into a common though massive information space [3], beaconing is one precondition for coordination in decentralized situations, where potential collaborators are unknown.

For larger organizations such as the Red Cross, UNICEF, and the military, beaconing does not describe tweet behavior. Such organizations have remote proxies and staff who can more adequately manage logistics. The smaller organizations seem to most benefit by the at-large digital volunteers who see the message beacons, and make the connections between potential partners, between requests and offers. It is in this "wired wilderness" [3] of massively distributed information spaces that well-attuned listeners detect and capitalize on the latent potential for coordination of teams on the ground.

Designing for the Decentralized Work of Disaster

Two implications for designing future ICT support during disaster response arise from this research. First, to enable efficient preparation and rapid response, it is important to connect teams on the ground (information providers) with teams preparing to deploy (information seekers). One way to support this need is to create an online destination where seekers and providers can find each other directly and exchange information. This method is being attempted by Sahana (sahanafoundation.org) and Ushahidi (ushahidi.com) though without particular attention to the details of medical response. Another way would be to augment the work of human agents with artificial agents to actively monitor social media statuses to find matches. Second, medical responders shared information about their needs but they were not the people to mediate between seekers and providers; this task was done by remote digital volunteers. This demonstrates a proof of concept that linking those on the ground with "connectors" who, as their primary task seek to make matches between needs and offers, can lead to a resolution of the problem. In other words, the already decentralized activity can become further decentralized by pushing some information functions to others outside harm's way. Instead of waiting for the crowd to surface its capacities in the moment, it is also possible to foster specific relationships during the pre-deployment phase with volunteers who can act as the remote proxies that large organizations formally employ.

Effective coordination is a critical but often elusive ally in disaster mitigation. The tragedy suffered by Haiti reveals opportunities for improving medical response. Though social media were in relatively little use for coordination of this scale in early 2010, we see proof of existence of new behaviors that could support medical teamwork and information sharing, with the points of improvement occurring not only in the field but also, critically, at the time of preparation and pre-deployment.

REFERENCES

1. Bentley, R. et al. Ethnographically-informed systems design for air traffic control. *Proc. CSCW 1992*, ACM Press (1992), 123-129.

2. Berman, P. Decentralized again. *Datanation 16*, 13 (1970), 141-142.

3. Bertelsen, O.W. and Bødker, S. Cooperation in massively distributed information spaces. *Proc. ECSCW 2001*, Kluwer Academic Publishers (2001), 1-17.

4. der Heide, A. *Disaster Response: Principles of Preparation and Coordination*. Mosby Inc., 1989.

5. Evaristo, J.R., Desouza, K.C., and Hollister, K. Centralization momentum: the pendulum swings back again. *CACM 48*, 2 (2005), 66-71.

6. FEMA. Use of social media tools at FEMA. *News Release FNF-09-040*, November 2, 2009.

7. Ginzburg, E. et al. Rapid medical relief—Project Medishare and the Haitian earthquake. *New England Journal of Medicine 362* (2010), e31.

8. Harvard Humanitarian Initiative. Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies. Washington, D.C. and Berkshire, UK: UN Foundation & Vodafone Foundation Technology Partnership, 2011.

9. Hauswald, M., Richards, M.E., Kerr, N.L., Schmidt, T.A., and Helderman, T. The Haitian earthquake and academic emergency medicine. *Academic Emergency Medicine 17*, 2 (2010), 762–764.

10. Heath, C., and Luff, P. Collaboration and control: Crisis management and multimedia technology in London underground line control rooms. *Computer Supported Cooperative Work 11*, 1-2 (1992), 69-95.

11. Hine, C. *Virtual Ethnography*. SAGE, 2000.

12. Juhlin, O., and Weilenmann, A. Decentralizing the control room: mobile work and institutional order. *Proc. ECSCW 2001*, Kluwer Academic Publishers (2001), 379-397.

13. Kendra, J.M. and Wachtendorf, T. Reconsidering convergence and converger legitimacy in response to the World Trade Center disaster. *Research in Social Problems and Public Policy 11* (2003), 97-122.

14. King, J. Centralized vs. decentralized computing: Organizational considerations and management options. *ACM Computing Surveys 15*, 4 (1983), 319–349.

15. Kreiss et al. Early disaster response in Haiti: The Israeli field hospital experience. *Annals of Internal Medicine 153*, 1 (2010), 45-48.

16. Leskovec, J., McGlohon, M., Faloutsos, C., Glance, N.S., and Hurst, M. Patterns of cascading behavior in large blog graphs. *Proc. SIAM Conference on Data Mining*, 2007.

17. Lorich, D., Eachempati, S., and Helfet, D.L. Doctors: Haiti medical situation shameful. *Special report to CNN*, January 25, 2010.

18. McCunn, M. et al. An organized, comprehensive, and security-enabled strategic response to the Haiti earthquake: A description of pre-deployment readiness preparation and preliminary experience from an academic anesthesiology department with no preexisting international disaster response program. *Anesthesia & Analgesia 111*, 6 (2010), 1438-1444.

19. PAHO/WHO. Earthquake in Haiti—One year later. *Report on the Health Situation*, January 2011.

20. Pape, J.W., Johnson, W.D. and Fitzgerald, D.W. The earthquake in Haiti—Dispatch from Port-au-Prince. *New England Journal of Medicine 362* (2010), 575-577.

21. Qu, Y., Huang, C., Zhang, P., and Zhang, J. Microblogging after a major disaster in China: A case study of the 2010 Yushu earthquake. *Proc. CSCW 2011*, ACM Press (2011), 25-34.

22. Quarantelli, E.L., Taylor, V.A., and Tierney, K.J. Delivery of emergency medical services in disasters. *Preliminary paper # 46,* University of Delaware Disaster Research Center, 1977.

23. Schmidt, K. and Bannon, L. Taking CSCW seriously. *Computer Supported Cooperative Work 1* (1992), 7-40.

24. Starbird, K., Palen, L.A., Hughes, A., and Vieweg, S. Chatter on The Red: What hazards threat reveal about the social life of microblogged information. *Proc. CSCW 2010*, ACM Press (2010), 241-250.

25. Suchman, L.A. Office procedures as practical action: models of work and system design. *ACM Transactions on Office Information Systems 1*, 4 (1983), 320-328.

26. Starbird, K. and Palen, L.A. "Voluntweeters": Self-organizing by digital volunteers in times of crisis. *Proc CHI 2011*, ACM Press (2011), 1071-1080.

27. Tamura, Y. and Fukuda, K. Earthquake in Japan. *The Lancet 377*, 9778 (2011), 1652.

28. Tierney, K.J. Emergency medical preparedness and response in disasters: The need for interorganizational coordination. *Public Administration Review 45* (1985), 77-84.

29. United Nations. Situation report: Haiti Earthquake 2010, 1800 hrs 23 Jan 2010. http://reliefweb.int/node/342689

30. Vieweg, S., Hughes, A., Starbird, K., and Palen, L.A. Micro-blogging during the two natural hazards event: What Twitter may contribute to situational awareness. *Proc. CHI 2010*, ACM Press (2010), 1079-1088.

31. Zarocostas, J. Death toll in Haiti may reach 200,000. *BMJ 340* (2010), c331.