**Exploration of key stakeholders’ preferences for pre-hospital physiologic monitoring by emergency rescue services**

**Short title: Emergency rescue physiologic monitor preferences**

**Authors:**

**Alasdair J Mort Ph.D 1**

**Gordon F Rushworth MSc 2**

**Affiliations:**

**1 The Centre for Rural Health, University of Aberdeen, Inverness, Scotland, UK; 2 Highland Clinical Research Facility, Centre for Health Science, Inverness, Scotland, UK.**

**Corresponding author:**

Dr Alasdair Mort PhD, Centre for Rural Health, University of Aberdeen, Centre for Health Science, Old Perth Road, Inverness, IV2 3JH, Scotland, UK

E-mail: a.mort@abdn.ac.uk

Telephone: +0044 (0)1463 255 886

**Abstract**

**Purpose:** To gather preferences for novel pre-hospital physiologic monitoring technologies from emergency rescue services.

**Methods:** Qualitative semi-structured interviews and focus groups were conducted with three groups from UK Search and Rescue (SAR); 1) Extractors (e.g. SAR teams), 2) Transporters (personnel primarily responsible for casualty transport), and 3) Treaters (e.g. Emergency Department doctors).

**Results:** Three themes were defined; SAR casualty management, novel physiologic monitor potential, and physiologic monitor physical properties. Some SAR groups already employed physiologic monitoring but there was no consensus on which monitor(s) to carry or what to monitor and how frequently. Existing monitors also tended to be bulky and heavy and could be unreliable in an unstable environment or if the casualty was cold. Those performing monitoring tended to have only basic first-aid training, and their workload was often high particularly if there was more than one casualty. The potential benefits of employing a novel monitor were strategic and clinical; an opportunity for transmitting data off-scene in order to facilitate monitoring or generate advice (i.e. telemedicine) was also voiced. A range of more intuitive, physical properties was also raised (e.g. small/compact, lightweight).

**Conclusions:** SAR-specific technology should be simple to operate by those with less medical training, which means that clinical data interpretation and presentation should be carefully considered. It would be beneficial if novel monitors carried out a majority of the interpretation, allowing rescuers to proceed with their priority task of removing the casualty to safety.

**Key words: Rescue work, Emergency Medical Services, Patient Monitoring, Medical Device Design**

**1 Introduction**

**1.1 Search and Rescue**

Search and rescue (SAR) activity worldwide necessitates the assistance of a diverse range of specialist rescuers with unique skill-sets. SAR includes ground personnel such as mountain rescue teams (MRT) and cave rescue teams (CRT). In a broader sense ground SAR also includes ski patrollers who are responsible for locating injured or ill persons and transporting them to safety. SAR is also delivered and supported from the air by specialist helicopter crews, some with winch capability. Some of these aircrews, particularly in Europe, are staffed with anaesthetists as part of national legislation. Thus, the model of SAR delivery varies worldwide and between niche SAR providers within individual countries.

A 2005 survey reported that some 37,535 ground rescuers and 747 helicopters were involved in emergency medical service provision in the mountain areas of 14 countries in Europe and in North America – there were also almost 60,000 paramedics and over 1,000 physicians involved in air and ground mountain rescue [1]. A subset of European Mountain Rescue Teams (MRT) who are arguably some of the busiest in the world conducted 11,000 rescue missions on average each year between 1987 and 1997, assisting approximately 8,200 persons annually, of whom 6,600 (80 %) were injured [2]. These figures are small compared with the numbers of patients assisted by more conventional emergency medical services. However, the number of SAR casualties is still substantial considering the range of organisations and resources that may be required to come to the aid of just one casualty.

The evidence indicates that SAR casualties are more often than not male, aged between 10 and 69 years of age, and have a preponderance of injury [3-8]. A small proportion may be medically ill, and some may have no illness or injury at all – they may simply be lost, but could be suffering from exposure. However, SAR teams also attend to some casualties with life-threatening, multiple injury who are physiologically compromised. The management of these casualties is hindered by the SAR context itself, including factors such as inclement weather, high altitude, low environmental temperature and operating at night.

Removing SAR casualty clothing in order to make a clinical assessment is often not practical as it risks exposing an already potentially hypothermic casualty to the prevailing conditions. Most often, after vital initial assessment and stabilisation, the priority is to extricate the casualty to a place of definitive care as quickly as is safe and practical. This substantially reduces the opportunity for routine clinical monitoring on-scene and during casualty transport – as such, SAR casualty physiologic assessment tends to be conducted manually and intermittently. A recent survey of the medical equipment carried by MRT internationally identified that rescuers with basic first-aid training did not routinely carry electronic physiologic monitoring devices [9]. Fewer than one-third of those who responded carried a method of blood pressure measurement, although it was not defined if these were manual or electronic. This may be due in part to existing monitoring technologies not being entirely suitable for deployment in SAR.

**1.2 Electronic physiologic monitoring**

Few electronic physiologic monitoring technologies have been designed specifically for SAR use. Most multi-parameter systems are bulky and heavy and are destined for ambulances or in-hospital patient transport (i.e. the largest markets) – some of these technologies have been the subject of local, small-scale SAR trials, but anecdotally there is little evidence of them being used routinely [10,11]. There are a limited number of examples of prototype development in the SAR literature. Michahelles and co-workers have explored the application of wearable sensors in avalanche rescue. The precautionary measurement of blood oxygen saturation, body orientation and oxygen level in an air pocket was intended as a method of triaging in multi-casualty scenarios [12]. Also, Zhao and co-workers designed a system that recorded a SAR casualty’s electrocardiogram, breathing rate and movement using a Bluetooth®-enabled sensor belt. These data could then be transmitted using satellite communication to enable remote review [13].

We are aware of the development of novel wireless sensors such as the RESpeck breathing rate system designed by the Department of Speckled Computing within the School of Informatics at the University of Edinburgh, Scotland [14]. This non-invasive technology attaches to the abdomen and monitors the movement of the abdominal wall using an accelerometer. Also, commercial manufacturers such as Intelesens (Belfast, UK) have developed lightweight, wireless, multi-parameter systems that attach to the body using adhesive patches. The development of such technology, that is capable of being worn for days at a time, has been driven by a desire to enhance the at-home monitoring of persons with chronic conditions (i.e. telehealth applications). There is also evidence of the development of forehead-mounted, wireless pulse oximetry, specifically for pre-hospital use [15]. A variety of novel sensor systems have also been developed for the precautionary monitoring of personnel operating in hazardous environments (e.g. military and fire service personnel) [16,17].

Zhao and co-workers noted in their 2011 paper that ‘there are few mature products with fast positioning and remote monitoring in the (SAR) market: consequently, the market has an unmet demand for this type of product.’ This is consistent with our own knowledge in this field. However, given the developments in related clinical fields, it appeared that a SAR-specific physiologic monitor could become a reality. Facilitating and enhancing SAR casualty monitoring could allow earlier identification of clinical deterioration, resulting in quicker intervention and possibly improve casualty outcome. Given this potential, the aim of this study was to gather preferences for new generations of SAR casualty physiologic monitoring technologies.

**2 Methods**

**2.1 Design**

A qualitative approach was chosen in order to access real-world SAR views and opinions in depth.

**2.2 Setting**

A wide variety of persons involved in managing SAR casualties in the United Kingdom (UK) were recruited to the study. This was intentional in order to reflect the diversity of UK SAR. UK SAR teams are registered charities, and their members are volunteers who give up their time for free to attend call-outs. This was an interesting group to recruit from as a survey identified that only just over half of the UK SAR teams who responded had doctors present on every call-out, and as low as one-third of individual teams’ members were trained in first-aid [18]. This presented a unique challenge as most physiologic monitoring systems are designed for persons with a higher level of medical knowledge (e.g. physicians and paramedics). UK SAR teams also had a consistent annual casualty load of around 700 persons [3].

**2.3 Participant identification and recruitment**

A purposive strategy was employed to generate in-depth data from a wide variety SAR groups, maximising diversity – the aim, as is commonplace in qualitative research, was not to recruit a ‘*representative*’ sample per se, although it was essential that the key groups involved in UK SAR were included. Three technology user groups were defined: A – Extractors; B – Transporters; and C – Treaters. Extractors included groups responsible for assessing casualties and providing initial on-scene management. Transporters included those who delivered casualties from the incident scene to definitive care or onto another Transporter group. Treaters included Emergency Department physicians responsible for treating casualties upon arrival at definitive care. Treaters were included as they communicated with pre-hospital teams and were ultimately the end-point of casualty information flow. Groups were defined by their primary role.

Participants were initially contacted about the study via telephone or e-mail and were recruited directly by author AM with the assistance of SAR team leaders as necessary. All participants were asked to provide written, informed consent. A ‘snowball sampling’ approach was adopted, which exploited recruited participants’ networks of contacts [19] – as such, data collection proceeded iteratively. The final sample size was determined by data saturation, the point at which no new themes emerged during data collection – saturation was assessed across the entire sample and not within individual Extractor, Transporter or Treater groups.

**2.4 Data generation**

Qualitative data were generated using a combination of focus groups and semi-structured interviews. Focus groups were deemed appropriate for capturing the views and opinions of those operating in teams (e.g. mountain rescuers, helicopter crews). Interviews were used to access the views and opinions of team-members out-with a team environment.

Focus groups and interviews progressed according to a topic guide and were captured in full using a digital voice recorder. Recordings took place in familiar locations (e.g. place of work, team base) wherever possible. Interviews and focus groups were carried out over a period of 10 months from February to November 2008.

**2.5 Data analysis**

Voice recordings were transcribed in full and analysed using the Framework method [20]. Framework comprised five distinct processes beginning with familiarisation, which involved listening to recordings and reading transcripts in order to identify recurring themes and ideas. The second process involved identifying a thematic framework with which to index transcripts - to ensure consistency of analysis two researchers (author AM and an independent clinical academic) generated separate thematic frameworks from the first three transcripts. The researchers then discussed their differences to reach agreement on a single list of themes. The third process of indexing involved applying the agreed thematic framework to the transcript text using specialised software (Atlas.ti version 6.0.12 - Atlas.ti GmbH, Berlin). This software was also utilised in process four to chart the data according to the various themes – this preliminary step involved categorising each quote against the relevant theme or themes, summarising the relevant quotes and making initial deductions. The fifth and final process involved mapping and interpreting the data, identifying the range of views and opinions and considering explanations.

Data were validated by sending original transcripts and author-generated summaries to the members of two focus groups and to one interviewee – the respondents confirmed that the summaries were accurate reflections of their opinions. All participants were assigned unique codes to ensure anonymity, and all potentially identifiable data were removed from quotes.

**2.6 Ethical approval**

This study was approved by a UK National Health Service (NHS) ethics panel (North of Scotland Research Ethics Service).

**3 Results**

Five focus groups and ten semi-structured interviews were conducted with a total of 25 participants (see Table); 15 persons took part in focus groups, and ten in interviews. No persons chose not to participate.

**Table. Study participants (MRT – Mountain Rescue Team, CRT – Cave Rescue Team)**

Discussions focused around three key themes; SAR casualty management, novel physiologic monitor potential, and physiologic monitor physical properties. Themes, sub-themes and frequency of quotes for each sub-theme are presented visually in a Figure.

**Figure. Themes and sub-themes identified. Numbers in parentheses indicate the frequency of quotes for a particular theme.**

**3.1 SAR casualty management**

**Monitoring casualties**

Participants mentioned the current difficulty of monitoring SAR casualties and gaining access in order to attach monitoring equipment. This suggested that a physiologic monitor could deliver real value if designed appropriately.

*…except for speaking to a patient, you’ve got no way of monitoring them really. I mean you can check their pulse but that’s it really.*

**MRT doctor**

*…[the casualty] may be wrapped [up] and you may be in a stretcher where you’ve got a life jacket on him for whatever reason and it starts to become quite complicated to try and physically get at them.*

**SAR helicopter crew**

**Physiologic monitors already in use**

There was evidence of physiologic monitors already being employed in SAR. Transporter groups mainly employed multi-variable physiologic monitors that also acted as defibrillators. These more expensive monitors were supplied by their employer (e.g. ambulance service, helicopter operator). However, only one Extractor group possessed such complex monitoring – they were never sure about how many volunteers would attend an incident, and as such there was sometimes a trade-off about what equipment to take. Also, not every casualty required physiologic monitoring. The other monitors carried by SAR groups included pulse oximeters (standard and military spec), blood pressure cuffs and thermometers (glass and digital tympanic probes), although some (e.g. ski patrollers) carried none at all.

**Pros of current physiologic monitors**

Some participants felt that pulse oximeters were particularly valuable as they were generally simple to apply and operate, although they were not always reliable if the casualty was cold. Ease of use and simplicity were recurring themes:

*You can take that [monitor] out of the bag, you can put it on somebody and use it, having never seen it before, just because the machine basically tells you what to do.*

**MRT doctor**

Other positive features of physiologic monitors included having pictures on electrodes to aid placement. Electrode adhesive gel was also considered good and reliable.

**Cons of current physiologic monitors**

The key negative feature of the more complex physiologic monitors was their size and weight. They were often big and bulky, making them difficult to carry, particularly up hills or across difficult terrain – this issue was also mentioned by road ambulance crews. Physiologic monitors could also be adversely affected by environmental factors; for example, battery life could reduce substantially in the cold. Wired monitors were not ideal – rescuers had to find routes for the wires through clothing and insulating casualty bags. Then the monitor always had to stay close to the casualty. Also, the motion associated with casualty transport (and pulling wires) sometimes resulted in motion artefact (i.e. noise) and false alarms.

*We had to set the parameters on most of the alarms so wide to be almost useless, just because of the jogging around affected it…*

**MRT member**

*a) it’s annoying and b) it can unsettle the patient when they suddenly hear the monitors they’re attached to alarming. I mean we constantly check with the monitors so I don’t think you need anything other than a good clear display.*

**Ambulance paramedic**

**Rescuer workload**

Participants noted that their workload was often high during SAR. Their primary role was to remove the casualty to safety. However, they also needed to monitor and manage the casualty, sometimes under very difficult conditions. Again, this pointed at ease of use being critical.

*You’re taking someone off [the mountain], you’re thinking about where you’re feet are going. It’s maybe dark, you’re knackered, you’re worried about this and that.*

**MRT member**

*There’s only two of you in the back [of the helicopter]. If you have two casualties of significant severity injury-wise you are working like a dog.*

**SAR helicopter crew**

It appeared that most casualties had relatively minor medical problems, although SAR teams had to deal with life-threatening emergencies occasionally. This tended to increase workload and urgency, particularly when some groups were exposed to such situations relatively infrequently.

*…a large rock had gone through his leg and there was a huge amount of blood around and the end of his leg was hanging off, which was quite dramatic really.*

**MRT member**

**Rescuers’ first-aid competency**

Most UK rescue groups had team doctors, but they were not always able to attend incidents. As such, monitors needed to be operable by, and deliver an appropriate level of information to those with less medical training.

*But it’s fair to say that we rarely have a doctor actually out with us, and lay trained people are pretty much the highest qualification we have. We do occasionally have a trainee paramedic with us but as a rule we’re as good as it gets...*

**MRT member**

*…sometimes it’s a competent first aider that’s running the show…*

**MRT doctor**

This indicated that the priority should be to provide information at a level that can be understood by those with only basic first-aid training.

**3.2 Novel physiologic monitor potential**

We asked participants about how novel physiologic monitors might influence their practice. There were an almost equal number of quotes for potential benefits (n = 45) and potential negatives (n= 42). Respondents commented on these themes more than any other. This indicated that there was considerable debate around the use of novel physiologic monitors. Most respondents commented on both pros and cons, suggesting cautious acceptance.

The benefits of employing a novel, rescue-specific, monitor appeared to fall into two key classes; *strategic* and *clinical*. The strategic benefit lay in a monitor effectively taking responsibility for the task of casualty monitoring so that Extractors were able to focus on their priority task of removing the casualty to safety.

*That system [a novel monitor], if it worked well, would just win that argument cos you would just stick it on and go. You would just say, “well, no, we’re not playing, hat’s on, let’s go. Let’s get the guy off the hill ASAP,” unless this [novel monitor] told you otherwise...*

**MRT leader**

Also, if a monitor were able to identify deterioration in casualty condition then it might mean that the casualty reached care quicker.

*It might take that urgency of rescue up a couple of degrees such that you might be forced to perhaps risk life and limb, say, to get a helicopter in to evacuate somebody rapidly if they were unstable.*

**MRT doctor**

Participants’ opinions on the clinical benefit of a novel monitor were mixed. In one camp there were participants who predicted little immediate advantage; clinical intervention was restricted by the environment even if a doctor were available. However, one MRT doctor who originally predicted little benefit changed their position.

*…but I think you perhaps have to be a little bit more proactive and say, “if you can do these tests and they are reliable then should we be doing more?”…if you look at mountain rescue in Europe there is a lot more intervention on the hillside than there is in Scotland and their environment is arguably quite considerably harsher than the Scottish environment at times.*

**MRT doctor**

A cave rescue doctor also indicated that enhanced, reliable monitoring might facilitate more intervention.

*…but it will probably allow people who are paramedics or doctors to be a little more aggressive with how much analgesia they would give and possibly would guide you whether you would give fluids or not…*

**CRT doctor**

One MRT doctor who acted as a medical advisor to a national rescue committee body thought that a novel monitor could also be a useful research tool, capturing patient physiologic data under environmental conditions that would be ethically challenging to expose healthy volunteers to. This could also help to identify best practice for treating patients (e.g. strategies for managing the hypothermic).

*…we’re not that great at collecting vital signs, because it’s difficult. The information that we’ve got is quite patchy and there would be definite scope for a research project…this is really, really useful information because experimentally you can’t ever induce hypothermia.*

**MRT doctor**

Some doctors who were the end point of care (in the ED) or who provided advice to rescuers from their base (e.g. a GP practice) felt that it could be advantageous to view data remotely (i.e. telemedicine). Some rescuers already called up their team doctors for advice when they needed help, which provided reassurance – sending physiologic data for review could be an extension to this.

*…it [data] could go somewhere where a medical person could actually analyse this and actually feed information back to the crew that are doing the rescue.*

**ED physician**

*I have a ski patrol radio that I keep in the surgery and I can get back to them [ski patrollers] and say, “look, actually I don’t like the way his.....have you seen his pulse rate going up now, have you seen his respiratory rate changing. I’m not too happy about that....can you tell me what’s happening.”*

**Ski patrol doctor**

One SAR helicopter crew went so far as to suggest that if there was a live data feed then a remote medical expert could take over the responsibility for monitoring one casualty whilst the aircrew monitored another. Another SAR helicopter crew felt that receiving ‘pre-arrival’ data from the ground would help them to better prepare for managing the casualty once they were onboard (i.e. getting the necessary equipment out and ready). However, one ED physician, who was also a member of a MRT, felt that sending data ahead of the casualty would achieve little benefit – rescuers with basic medical training could achieve little in the remote and rural environment.

*…all I can tell our guys to do is, “yeah you’re givin them, doin that right, put them on oxygen, you’ve packaged them and bring them in, there’s nothing else these guys can do.” I think it [sending data ahead for remote expert review] would be useful but it’s not going to change things that much.*

**ED physician and MRT doctor**

They also voiced concern about how a remote advice system would operate in practice – the clinician reviewing data might not have emergency medicine training or the awareness of the difficulty of the SAR context. Also, it was unlikely that there would be one dedicated point of contact – this meant that advice could vary.

**3.3 Physiologic monitor physical properties**

Participants also expressed preferences for the form factor of physiologic monitoring devices – small, lightweight and robust technologies were of clear advantage. These more intuitive data are not presented in detail as they are a prerequisite for a physiologic monitor to operate in SAR (see Figure for a summary of the themes discussed by participants).

**4 Discussion**

This study generated a broad range of views and opinions on physiologic monitoring from a variety of groups involved in SAR casualty care. Importantly, a number of participants confirmed that a novel physiologic monitor did indeed have potential in SAR. However, in order to develop a system of real practical benefit there are two key clinical areas that require careful consideration; data interpretation and presentation.

It would appear sensible that a SAR-specific physiologic monitor should perform a degree of on-device clinical interpretation, particularly as users are most likely not to be medical experts. This interpretation would take place naturally after filtering to cope with the variability of data in this inherently unstable environment (e.g. during stretcher carry or helicopter transit). On-board interpretation should involve interrogating the data for pre-defined trends and patterns, as well as observing for any thresholds being crossed. If the system raised an alarm then it would be useful if this alarm could be graded or coded according to the severity of the potential issue identified. In general, alarms should be employed cautiously as stopping the rescue may not be practical and could even be counter-productive. There is a considerable body of evidence that a large proportion of alarms raised by physiologic monitors are false, even in highly controlled environments such as intensive care [21] – this may turn out to be a key challenge in development, and may apply to some physiologic channels more than others (e.g. breathing rate).

The suggestion that clinical data could be sent off-scene for remote expert interpretation is of interest. Telemedicine has been explored by one UK SAR team who sent ECG data from the hill-side to a nearby hospital [11]. However, the system was never used in anger, mainly due to only a minority of SAR casualties experiencing medical illness (typically around 10 % in the UK). A number of other teams simply radioed their team doctor for advice. One of the barriers to this has been having the necessary communications structure and bandwidth in place, which is a particular issue in remote areas (personal communication with SAR communications expert). The other issue involves identifying which person is responsible for reviewing the data, particularly if a SAR team’s physician is unavailable. However, it is not inconceivable that given the necessary clinical consideration and resource, and technical development (e.g. satellite and 4G communication) that this concept could come to fruition in the future.

The evidence indicated that the mode of presentation of SAR clinical data should move away from the more traditional numbers and graphs strategy common in other clinical contexts (although these data should be accessible if required). Rather, the physiologic status of the casualty should be triaged and displayed simply, potentially combining the data from several channels into a single indicator. It would be essential for the user to determine the casualty’s physiologic status as quickly as possible. Also, the system should potentially remind users to carry out their own manual checks of casualty physiology, whenever is appropriate – such an electronic monitoring system should play its part as a helpful adjunct to manual assessment, but not replace it.

The International Commission for Mountain Emergency Medicine (ICAR MEDCOM) has recently published recommendations for the level of monitoring equipment carried by MRT [9]. Non-physician medical kits should include a pulse oximeter (monitoring saturation of blood with oxygen and heart rate), an epitympanic thermometer (monitoring ‘core’ body temperature) and a method for measuring blood pressure. Pulse oximetry is a good platform as it is simple to apply – there is also potential for a breathing rate signal to be derived from the pulse waveform (e.g. www.phoneoximeter.org) [22]. However, as was acknowledged earlier, pulse oximetry data can be inaccurate or not generated at all if a casualty is cold – this may be solved by applying heated gloves, which are now commonly available. In general, SAR physiologic monitoring should be achieved with as few separate sensors as is possible – this will minimise application time and casualty exposure to the elements.

Implementing a novel physiologic monitor across SAR services represents a particular challenge. So far, the limited number of evaluations in UK SAR have been carried out by individual teams. This may be because some teams have more cause to monitor the physiology of their casualties – for example, some may manage more trauma than others. UK SAR teams are also in charge of their own budgets, and requests for more *standard* items (e.g equipment maintenance and repair, insurance) may be more pressing. However, in order for a novel monitor to be implemented and evaluated robustly in the UK and elsewhere then it would be important to include several teams – this evaluation would most likely take place in conjunction with a technology partner and a group of independent evaluators. We recommend this as a crucial ‘next step’ to evaluating definitively the potential of novel monitors, to finalising the design and functionality of technology (if novel monitors do indeed deliver some benefit in SAR), and to developing monitoring initiatives at a national, if not international, level. This is particularly important as this study identified the presence of rigid hierarchies within some UK SAR teams, which appeared to hinder innovation in patient care:

*…you can upset people too much if you...and that is why I am very cautious about saying too much because I am very junior and not particularly well known within the rescue service and I think if you just sit back for a few years and kind of just get experience and then that’s the time to change things. Well not change things, improve things…so I’m just going to sit back and let them get on with it and maybe when I get old and wise I’ll make some suggestions.*

**MRT doctor**

There were some limitations to this study. Only groups involved in SAR casualty rescue and treatment in the UK were included, the majority of who have only basic first-aid training. It is possible that SAR groups from other countries, and in particular professional rescue services, will have expressed a different range of opinions. However, we consider that these data are transferable as the first responder in mountain rescue worldwide is commonly someone with only Basic Life Support training [9]. Secondly, the intensive, in-depth nature of qualitative research meant that a relatively small number of participants were recruited to the study, compared with the larger numbers that might have been achieved using a quantitative survey methodology, for example. Finally, we assessed for thematic saturation across the entire sample of 25 participants. This afforded excellent variety in the sample, which reflected the fragmented nature of UK rescue as a whole, but did not achieve saturation within individual groups (i.e. Extractors, Transporters, Treaters). As such, results within individual groups may not reflect the full range of views and opinions.

**Conclusions**

This study captured a unique set of preferences for the development of a SAR-specific physiologic monitor. An appropriately designed system could reasonably be expected to confer some benefit to SAR personnel and their casualties. This may improve clinical outcome (immediately or later) if trustworthy data are presented appropriately to a mostly non-expert audience. Sending these data off-scene may facilitate the provision of assistance from a remote medical expert, but it is questionable as to whether current communications systems have the necessary capacity to achieve this reliably. The next inventive step would be to develop SAR-specific software to capture data from a suitably robust and lightweight multi-parameter physiologic sensor. This technology should then be evaluated robustly across several SAR teams, in conjunction with a technology partner and independent evaluators. The market for such a device could be international, including ground rescuers and those involved in air support. There may also be the opportunity to introduce such technology into wider pre-hospital care where environmental conditions can also be extreme.

**Acknowledgements**

The authors wish to thank all participants for giving their time to take part, and to the University of Aberdeen Sixth Century Fund and Highlands and Islands Enterprise (Inverness and East Highland) for co-funding the research.

**Competing interests**

None.

**REFERENCES**

1. Brugger H, Elsensohn F, Syme D, Sumann G, Falk M (2005) A survey of emergency medical services in mountain areas of Europe and North America. High Alt Med Biol 6:226-237
2. Lischke V, Byhahn C, Westphal K, Kessler P (2001) Mountaineering accidents in the European Alps: have the numbers increased in recent years? Wilderness Environ Med 12:74-80
3. Mort A, Godden D (2010) UK Mountain Rescue Casualties: 2002-2006. Emerg Med 27:309-312
4. Hearns ST (2003) The Scottish mountain rescue casualty study. Emerg Med 20:281-284
5. Ela GK (2004) Epidemiology of Wilderness Search and Rescue in New Hampshire, 1999-2001. Wilderness Environ Med 15:11-17
6. Heggie TW, Heggie TM (2008) Search and rescue trends and the emergency medical service workload in Utah's National Parks. Wilderness Environ Med 19:164-171
7. Hung EK, Townes DA (2007) Search and rescue in Yosemite National Park: A 10-year review. Wilderness Environ Med 18:111-116
8. Marsigny B, Lecoq-Jammes F, Cauchy E (1999) Medical mountain rescue in the Mont-Blanc massif. Wilderness Environ Med 10:152-156
9. Elsensohn F, Soteras I, Resiten O, Ellerton J, Brugger H, Paal P (2011) Equipment of Medical Backpacks in Mountain Rescue. High Alt Med Biol 12:343-347
10. Ellerton J (1992) The use of a portable monitor in mountain rescue. J Br Assoc Immed Care 15:19-22.
11. InfoLab21, Lancaster University, UK (2007) Mountain Rescue Project www.infolab21.lancs.ac.uk/research/wireless\_and\_mobile\_communications.php. Accessed 7 October 2009
12. Michahelles F, Matter P, Schmidt A, Schiele B (2003) Applying wearable sensors to avalanche rescue. Comput Graphics 27:839-847
13. Zhao J, Zheng B, Zhang X, Wang J, Zhou Y, Chen S, et al (2011) The Design and Implementation of a Rescue Terminal with Vital Signs Telemonitoring Based on Beidou 1 Navigation Satellite System. Telemed e-Health 17:76-79
14. Drummond GB, Bates A, Mann J, Arvind DK (2011) Validation of a new non-invasive automatic monitor of respiratory rate for post-operative subjects. Brit J Anaesth 107:462-469
15. Mendelson Y, Duckworth RJ, Comtois G (2006) A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring. Proceedings of the 28th IEEE Engineering in Medicine and Biology Society Annual International Conference, New York City, USA, Aug 30 – Sept 3. Volume 1, 912-915.
16. Shaw GA, Siegel AM, Zogbi G, Opar TP (2004) Warfighter Physiological and Environmental Monitoring: A Study for the U.S. Army Research Institute in Environmental Medicine and the Soldier Systems Center. MIT Lincoln Laboratory. Report no. ESC-TR-2004-077.
17. Curone D, Secco EL, Caldani L, Lanatà A, Paradiso R, Tognetti A, Magenes G (2012) Assessment of sensing fire fighters uniforms for physiological parameter measurement in a harsh environment. IEEE T Inf Technol B 16:501-511
18. Hearns ST (1999) First aid training and equipment in UK mountain rescue teams. Prehosp Immediate Care 3:215-218
19. Kuzel A (1992) Sampling in Qualitative Inquiry. In: Crabtree B, Miller W (eds) Doing Qualitative Research*.* SAGE Publications, Newbury Park, CA, pp 31-44
20. Ritchie J, Spencer L (1994) Qualitative data analysis for applied policy research. In: Bryman A, Burgess RG (eds) Analyzing qualitative data. Routledge, London, pp 173-194
21. Cvach M (2012) Monitor alarm fatigue: an integrative review. Biomed Instrum Techn 46:268-277
22. Addison PS, Watson JN, Mestek ML, Mecca RS (2012) Developing an algorithm for pulse oximetry derived respiratory rate (RRoxi): a healthy volunteer study. J Clin Monit Comput 26:45-51