REMOTE REVERSE TRIAGE IN AVALANCHE RESCUE

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ABSTRACT

Remote reverse triage is an effective tool to optimize survival chances in companion and organized avalanche rescue. In the majority of cases avalanche accidents with multiple burials lead to a shortage of rescue resources, the rescue party is usually incapable of providing optimal rescue efforts to all buried subjects simultaneously. The shortage of resources leads to a selection based on the chronological order the buried subjects are located and excavated.

Remote reverse triage algorithms optimize this sequence by targeting survival chance optimization for all the buried subjects. Similar triage algorithms can be found for rescue environments with a comparable set of problems, i.e. earthquake rescue.

Unfortunately, triage does not have an appropriate place in course curriculums today and the image of triage suffers from irrational myths. It is an important task of modern educators to inform trainees in a rational manner about triage algorithms starting at a very early stage in avalanche rescue training.

Keywords: REVERSE TRIAGE, AVALANCHE RESCUE, URBAN SEARCH AND RESCUE, VITAL DATA SENSING

1. INTRODUCTION

In avalanche rescue, particularly in companion rescue, a shortage of resources is very common. When it becomes impossible to provide optimal care to all buried subjects simultaneously, the rescuers are forced to choose who will be searched for, excavated and medically treated first.

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Triage deals with the *fact* that the rescue for buried subjects needs to be split up in a sequence of actions where not every buried subject can be treated with the same priority. Triage simply covers the *optimization of the sequence* of actions with the aim to provide the highest survival rate to the highest number of all the buried subjects.

1.1 A brief update on multiple burial statistics

Triage measures need only to be applied in case of multiple buried subjects. This is an update from the work published by Genswein and Harvey at ISSW 2002, but focusing on a more recent period of 10 winters starting at 1994/95 to 2004/05. Only completely buried, recreational avalanche victims with no visible parts have been taken into account, as these constitute the only relevant group in this context.

Number of buried subjects and avalanches within the selection criteria:

Total number of avalanches: 176

Total number of buried subjects: 231

Total number of avalanches with only one buried subject: 138

Percentage of avalanches with multiple buried subjects: 21.6% (= prevention relevant figure)

Percentage of buried subjects in multiple burial situations: 40.3% (= rescue relevant figure)

Percentage of buried subjects involved in an accident with 3 or more buried subjects: 19.5%

Percentage of buried subjects involved in an accident with 4 buried subjects: 5.2%

Compared to the 1970/71 to 1998/99 observation period (Genswein – Harvey, 2002), fortunately, the percentage of buried subject in a multiple burial situation has decrease from 61.2% to 40.3% and no accident with more than four completely buried subjects have occurred. However, still 40.3% of all buried subjects in Switzerland with no visible parts are involved in a multiple burial situation. Multiple burial search and triage strategies are therefore an important part of the avalanche rescue training.

2. TYPES OF TRIAGE

Triage is the prioritizing of resources to maximize survivors in a disaster with multiple victims. Triage strategies have to take into consideration the particular characteristics of the specific rescue scenario.

2.1 <u>*Triage*</u>

General triage sorts patients based on the severity of their injuries with the aim to treat those ones in the worst conditions first. Statistically, this is the most appropriate strategy for situations where the ratio between the rescue problem and the available rescue resources is still reasonably good. In this case, the rescue party is short, but not completely depleted of resources. In this state, it is important to treat the patients in the worst conditions first and these are the ones who absorb the greatest amount of rescue resources. In general triage, the life of a patient who needs to wait for an extended time to be treated is not ultimately in danger. Postponement of treatment may be uncomfortable, but is not life threatening.

2.2 <u>*Reverse triage*</u>

Reverse triage sorts patients – or buried subjects in this treatise – based on the severity of injuries with the goal to treating those who need the least amount of rescue resources first to increase the total number of lives saved. Reverse triage is applied in situations where the ratio between the rescue resources and the rescue problem is bad, such as disaster situations. In order to maximize the survival rate of the total number of victims, it becomes necessary to postpone actions for patients who require lots of rescue resources with marginal survival chances. In reverse triage, the life of a patient who needs to wait for an extended time to be saved by the rescue system may be in danger.

2.3 <u>*Local triage*</u>

Triage or reverse triage applied in a case where rescue personnel have direct, physical access to the patient.

2.4 <u>*Remote triage*</u>

Triage or reverse triage applied in a case where rescue personnel do not have direct, physical access to a buried or trapped subject.

3. TRIAGE IN AVALANCHE RESCUE

The environment of avalanche rescue fulfills the two elementary criteria for triage measures:

1: Buried subjects do not die simultaneously
2: Limited rescue resources are very likely

The specific characteristics of a rescue in an avalanche accident make it an appropriate environment for remote triage:

1: Physical access to the buried subject is not directly possible, but requires a time consuming excavation effort.
2: The time required to excavate a buried subject leads to a further reduction of survival chances of all remaining buried subjects.
3: The time required to apply a triage decision is very small compared to the excavation time: t (search) << t (excavation)

In an avalanche rescue, remote reverse triage is applied when there is a shortage of rescue resources prior to the buried subjects being excavated. When physical access is acquired, local triage or local reverse triage is applied. Local reverse triage often needs to be applied if multiple patients need CPR, which usually exhausts the rescue resources very quickly.

This paper focuses mainly on remote reverse triage in avalanche rescue.

3.1 Statistical evidence

The Swiss avalanche accident database shows that the buried subjects who have survived the accident have a shorter burial duration compared to the buried subjects who died. Shortening the burial duration of buried subject with promising survival characteristics (small mechanical impact, shallow burial depth, measureable vital signs) therefore increases the survival chances of a collective of people caught in avalanches.

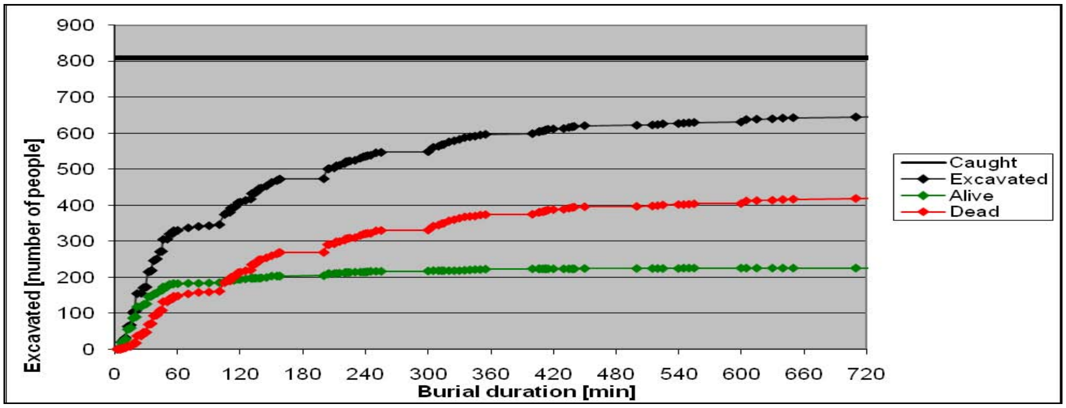

Fig 1:

Accident data winter 1970/ 71 to 2004/05 for completely buried subjects:
After 60min, few buried subjects have been found alive.

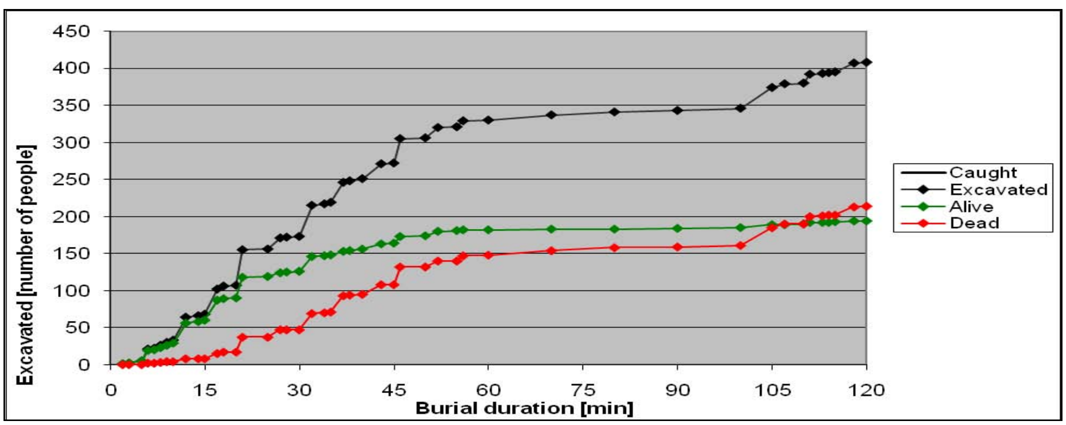

Fig 2:

Accident data winter 1970/ 71 to 2004/05 for completely buried subjects:
84% of buried subjects who were excavated within the first 20min survived the accident. At 30min this percentage is 73%, at 45min 60% and at 60min 55%.

3.*2 Remote reverse triage in avalanche rescue*

3.2.1 Remote reverse triage criteria

3.2.1.1 Terrain evaluation

The mechanical impact to subjects caught in an avalanche depends on terrain and vegetation characteristics. Falls over high cliffs, into seracs or crevasses reduces survival chances. Collision with rocks and in particular trees are likely to cause severe mechanical impact, strongly reducing survival chances. Higher survival chances are more likely in gentle run out zones with no obstacles.

3.2.1.2 Burial depth

Mortality of avalanche victims increases with increasing burial depth. Based on a Brugger/ Falk study (1994), it was not possible to prove that a deep burial depth was the cause of higher mortality, so it was suspected that death was influenced primarily by an extended burial time, not by a higher mortality within the avalanche. During field testing of remote vital data sensing devices for avalanche victims, measurements of the compaction of the buried subject showed an increased mechanical pressure associated with increased burial depth. This new data implies that mortality is not only influenced by extended burial duration, but as well by unfavorable survival conditions related to increased burial depth.

Deep burials fall in the category of buried subjects which require a lot of rescue resources with very limited survival rates.

3.2.1.3 Distance between rescuer and buried subject

The distance between the rescuer and the buried subject influences rescue times and therefore is a remote reverse triage criteria.

The distance criterion is the most commonly applied triage criteria, as most rescuers are not aware that by choosing the closest buried subject, they already made an active triage decision.

3.2.1.4 Vital data of the buried subjects

Vital data of buried subjects can be obtained today with certain avalanche rescue transceivers. Both the buried subject and the rescuer need to be equipped with such avalanche transceivers capable of sensing, transmitting and receiving this vital information for it to be useful. The availability of this life sign information from the body of the buried subject reduces uncertainty about survival chances.

4. VITAL DATA DETECTION

4.1 History

Vital data detection on buried subjects wearing a vital data capable avalanche rescue device only started a few years ago.
A study of Florian Michahelles, ETH Zürich, Switzerland on “Extreme Prototyping” applied detection for:
- O2 saturation
- ECG
- Heart and lung activity by radar
- Respiratory cavity detection by CO2 measurement
- Core temperature measurement

This scientific project did not make it to the industrialization of the technology, but launched an important discussion on the subject of vital data sensing in avalanche rescue.

4.2 Technical Development

Many of the detection technologies applied by Michahelles cause discomfort to the wearer of the sensing device or the required technology is not applicable with today’s technology in an avalanche rescue environment. During the development of the vital data sensing solution in use today, the best compromise between field applicability, expected compliance and reliability of detection had to be carefully evaluated.
Three dimensional acceleration devices meet these requirements and boundary criteria best. Such micro-electro-mechanical systems (MEMS) based sensors can detect acceleration in the amplitude of 1mg, are relatively affordable and have only limited power requirements. Due to the extremely low mass of the sensor, this technology is very tolerant of mechanical shock.
The sensors are sensitive enough to detect vital data such as breathing or a heart beat without having to carry it as an implant or directly appled to the skin. The sensor is mounted in the avalanche rescue transceiver.
Every detectable acceleration is interpreted by the system as a sign of life.

4.3 Analysis and procedures with vital-sign data

The data measured by the sensor needs to be analyzed and processed to provide utility as a remote reverse triage criteria.

Procedures and criteria have been developed in close collaboration with ICAR Medcom and other mountain rescue physicians.
The systems applied today know two different states to characterize the survival chances of a buried subject.
1. “Increased survival chances” for buried subjects which show measurable vital signs.
2. “unknown survival chances” for buried subjects without measureable vital signs.

4.4 Long term survivors

As the body of the buried subject increasingly suffers from hypothermia, it has to be assumed that the reliability of detection is decreased as the amplitude of the measurable accelerations decreases. For buried subjects to become hypothermic, they need to be buried in snow for at least 35 min. Buried subjects who have survived the first 35min must have a respiratory cavity and do not suffer from severe mechanical impact. Buried subjects fulfilling the criteria of measureable vital signs during the first 35min burial duration are therefore potential hypothermic long term survivors and are categorized with “increased survival chances” for the remaining burial duration independent of measureable vital signs after passing the 35 minute time line. Medically, the hypothermal long term survivors often show higher chances of successful resuscitation without residual brain damage.

4.5 Field testing

The currently available sensing technology of vital sign capable transceivers has been field tested with a real buried subject in a controlled environment. Out of the 25 burial situations, four were in two meters burial depth with the following burial durations: 1:41, 1:31, 1:15 and 1:27 (hours:minutes). The remaining 21 burial situations where between 100cm and 130cm deep and therefore close to the median value for skier triggered avalanches in Switzerland. Burial duration was typically between 20 min. and 60 min.

The buried subject was boot packed in high density spring snow on a glacier close to the mountain station Jungfraujoch, Switzerland at 3450m elevation. The buried subject was equipped with an Avalung breathing device to insure survival so that he would still be able to write the paper you are reading now. The test series were a cold and “interesting” experience. It is strongly advised not to experience, let alone repeat it in an “uncontrolled setting.”

The results of the field test show a reliability of about 98% chance of detection for vital signs, if the device is carried according to the official recommendations by the manufacturers of vital data capable avalanche rescue transceivers.

5. COMMUNICATION OF VITAL DATA INFORMATION

Vital data capable avalanche rescue transceivers communicate vital data information on a frequency separate of the search frequency from the buried subjects to the rescuers.

6. RECOMMENDATION FOR REMOTE REVERSE TRIAGE IN AVALANCHE RESCUE

In case a rescue mission suffers from a shortage of resources, the application of remote reverse triage is recommended in the following sequence:

1: Prioritize sectors of the avalanche with higher survival chances: No forest, no crevasses, no seracs, and no high cliffs
2: Life saving measures for non- or partially buried subjects
3: Search for buried subjects with “increased survival chances” based on vital signs (where available).
4: Excavate buried subjects with “increased survival chances” in shallow to medium burial depth.
5: Search and excavate buried subjects with “unknown survival chances” in shallow to medium burial depth.
6: Excavate buried subjects with “increased survival chances” in high burial depth.
7: Excavate buried subjects with “unknown survival chances” in high burial depth.

7. ETHICAL ISSUES WITH VITA DATA CAPABLE TRANSCEIVERS

The fact that not all buried subjects are equipped with vital data capable avalanche rescue devices may temporarily lead to unfairness in the treatment of buried subjects without vital data capable avalanche rescue devices.
This temporal unfairness needs to be weighed against the advantages of the vital data capable avalanche rescue devices in a long term perspective.

A buried subject should not have a rescue advantage based merely on the presence of a device capable of communicating vital data. Only when the presence of detectable vital signs on the body of the buried subject via this new technology give a clear indication against other known priority defining criteria such as burial depth should such information affect prioritization in remote reverse triage.

8. APPLICABILITY OF REMOTE REVERSE TRIAGE IN COMPANION RESCUE

Unfortunately, triage does not have an appropriate place in today's course curriculums and the image of triage suffers from irrational myths. It is an important task of modern educators to inform trainees in a rational manner about triage algorithms starting at a very early stage of avalanche rescue training.

A large field test carried out by Genswein and Eide in 2008 demonstrates that even companion rescuers with minimal training can apply remote reverse triage criteria without problems.

Field example:

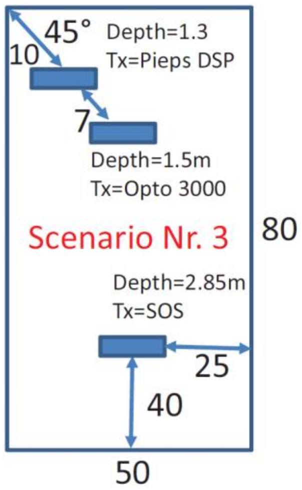

Fig 3:
Avalanche rescue scenario.
All measures in meters

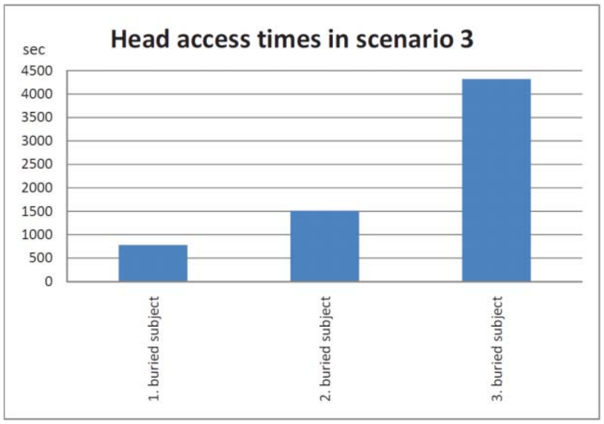

Fig. 4:
Head access times in scenario 3.

The head access times measured in scenario 3 easily show the effect of remote reverse triage by burial depth. Entering the field from below, the closest buried subject was very deep so that the companion rescuers decided to directly proceed to the remaining two buried subjects. The head access times speak slearly: Starting to dig at the first buried subject with high probability would have lead to a very bad outcome for all three buried subjects.
Thanks to a properly applied triage decision, two subjects benefited from head access times with reasonable chances of survival.

9. SIMILARITIES WITH EARTHQUAKE RESCUE ENVIRONMENTS

In the aftermath of large-scale earthquakes, where the high number of collapsed buildings calls for a great deal of search and rescue resources, the situation is similar as in multiple-victim avalanche rescues. In such events, there is no community that has the resources to start operations at all rubble sites simultaneously. Despite the increasing number and capacity of international urban search and rescue (US&R) teams, earthquakes in large urban areas will always demand decisions regarding prioritization of the rescue efforts.

9.1 Building-Collapse Triage

Urban search and rescue workers have long since been aware of the fact that in these large earthquakes not everyone can be saved and they have to choose which buildings to start rescue attempts. In the past, the method has been to ask people on the street and family members; is anyone missing? Could voices be heard from the rubble? If they got a positive answer they would follow that lead. This is now considered an unacceptable method as rescue workers can easily be lead astray by hope of a live rescue by those asked.

It is important to give rescuers tools to make quick sound decisions and move away from the emotional part of deciding whom to rescue first. The basic triage factor is simply the number of confirmed live people entrapped. Nonetheless, situations arise where this oversimplifies the issues faced by the rescuers and calls for a more detailed triage process.

9.2 International Guidelines

Organized US&R first gained attention after the 1985 Mexico City earthquake; however it was the uncoordinated response to the 1988 Armenia earthquake that started the momentum that lead to the establishment of the International Search and Rescue Advisory Group (INSARAG) in 1991. INSARAG is an open organization of international US&R teams. One key function is to develop guidelines in order to ease cooperation and coordination among teams during operations. It may therefore be considered as an equivalent of the International Commission for Alpine Rescue ICAR on the mountain rescue side.

Various teams have in the past developed their own triage methods. For instance, Dave Hammond from California, USA, developed a method for engineers based on a scoring system using factors such as size of building, use and occupancy rate. The method was adopted outside the US, but did not gain an international foothold. The concept of an international triage guideline based on a 5-Step approach was first introduced at an INSARAG Team Leaders meeting in 2002. The concept was well received and developed further through international collaboration the following years. It was formally put in the INSARAG Guidelines in 2006, and later updated in 2007 (1).

The Guidelines are not binding and there is no record of how many teams have adopted the 5-Step Approach into their operational procedures. Numerous countries, such as Sweden, UK, China, Turkey and Pakistan have received training. Developing and implementing international standards takes years. There are anecdotes of the method being used but no systematic research on its effectiveness.

9.3 The 5-Step Approach to US&R Work-Site Triage

The method is based on five basic steps:

1. Determining the zone that the triage should cover. Mobility and size of the assessment team will affect the size of the triage zone;
2. Identifying the totally and partially collapsed structures within the designated zone as potential work-sites.
3. Collecting information from locals on issues that may affect the triage, including missing persons, structure-related factors and prior rescue attempts.
4. Placing the building in a triage category
5. Determining the order of priority of the work-sites based on the local information and triage category. The estimated time to access victims is taken into account, which will depend on the capability of the team.

Four out of the five steps are straightforward. Step number 4 however, requires knowledge of the eight triage categories and training in how to apply them. The triage categories (A-H) are a combination of three triage criteria:

1. Victim information (confirmed that victims are alive, or information is unknown)
2. Void space (the rescue worker must estimate the size of the voids from outside the collapsed structure; big voids have higher priority)
3. Structural stability (the rescue worker must judge the stability of the rubble pile; stable piles have higher priority)

The INSARAG guidelines explain the definitions of big and small voids, and how to judge stability. The Triage Tree (Figure 6) demonstrates a decision-making process for determining a triage category.

The thought process is such that the smaller the void space the victims are in, the more likely they are injured, are less mobile and therefore less likely to survive the wait for the teams to reach them; and the more stable the rubble pile the less time needed for shoring and less time to access the victim will be shorter.

The method was designed for one team to triage an area for its own operation, but the method can of course be used when dispatching many teams. Furthermore, the method is designed to be used in large buildings and is not particularly useful in areas with small houses of poor construction that collapse completely, leaving very stable rubble piles but virtually no voids.

9.4 Time of Access to Victim

By-standers and light teams rescue victims that are easily found and easy to reach. The medium and heavy teams focus on victims more deeply entombed.

Heavy urban search and rescue demands heavy logistical support. The teams are large with heavy equipment, especially when compared to avalanche rescue teams. Hours and days may pass before the rescue personnel get to the site. Due to the scarcity of heavy teams, such teams have been sent to disasters across continents. The question of whether the time delay is worth the effort in view of the number of live finds is debated. Experienced international teams are now training local teams in the INSARAG procedures which will shorten the travel time during an internationally coordinated response.

US&R in large buildings is very time-consuming. A single rescue may easily take hours. The operation in the Murrah building in Oklahoma City in 1995 took 16 days. The live recoveries were all completed in the first 24 hours.

9.5 Survival Times

The drop-off rate for survival is very high. A literature search by Barbera and Cadoux (2) in 1991 indicates a dramatic drop-off in live finds during the 24-48 hour post-earthquake period. For victims with severe injuries where every minute counts, the chances of survival are slim if they cannot be rescued immediately by by-standers. There are many factors that contribute to survival time in a collapsed building, including ambient temperature and access to food and water. A study by Macintrye, Barebera and Smith (3) reports live finds after 2 days in 18 out of 34 earthquakes they investigated. Most of them occurred within 5 days of the earthquake, the longest reported survival was 14 days.

9.6 Vital-Sign Detection

Significant development has been made since 1985 in technical search, borrowing technology used in mining accidents. Technical search devices are acoustic and seismic listening devices designed to detect and locate victims. Technical search is based on two factors related to vital signs; consciousness and mobility. The victims need to be conscious in order to respond to calls and they need to be able to move in order to knock (Fig. 5).

Victim	Rescuer	Device
Consciousness? Can the victim shout?	Calls into the rubble and waits for an answer.	Detects acoustic waves (sound)
Mobile? Can the victim knock on rubble?	Knocks on the rubble and waits for the victim to knock in response	Detects Seismic waves (vibration)

Fig. 5:
Vital-signs in earthquake rescue

After a victim has been detected the sensors are moved, through a triangulation process, in order to pinpoint his location.

Video cameras are used in technical search. Miniature cameras are mounted on telescopic poles attached to a screen for direct visual search. Video cameras mounted on miniature robots have been introduced into US&R, but have not gained popularity among rescue workers.

Triage teams do not use any equipment, as it may slow them down when working in a wide area. The equipment is used as soon as it is appropriate.

9.7 Reverse Triage

The odds are against live finds for deeply entombed victims. Searching for victims in large complex collapsed structures can be like searching for a needle in a haystack. Realizing this, earthquake triage methods focus the attention on those who have the highest chance of survival, in reverse to traditional triage.

It is of the utmost importance that advance teams be dispatched to the area immediately after the time of impact quickly collects information and makes correct decisions on where to dispatch the teams, in order to increase the team’s chances of saving as many lives as possible.

Due to the overwhelming lack of resources and low number of live rescues, US&R teams are very open to exploring methods that could possibly save more lives in future earthquakes. The problem they face, so to say, is that there are so few events that years may pass before they get to test them, which can affect their interest.

The training is based on studying photographs of collapsed buildings. The method does not require a specific educational background; however the more experience rescuers have in seeing collapsed buildings from the inside the more comfortable they feel in making the necessary judgments. The notion of reverse triage has to be explained during the training, but rarely disputed.

10. CONCLUSIONS

The application of triage in avalanche rescue as well as in earthquake rescue leads with high probability to higher survival rates for the collective of buried subjects. Currently, there is in both fields of application no statistical proof for the efficiency of triage, as the required statistical base is missing (earth quake rescue) or not specific and precise enough data is available (avalanche rescue).

Triage needs to receive an appropriate place in course curriculums and needs to be treated as a serious, efficient and integral part of search rescue strategies in earthquake as well as in avalanche rescue. Educators need to inform trainees in a rational manner about triage algorithms starting at a very early stage of the training.

10.1 Comparison of rescue environments

There are strong similarities between avalanche and earthquake reverse triage. In an earthquake situation the condition of the collapsed buildings is judged as it gives an indication of the survival chances of the victim. This is similar as to judging the terrain during an avalanche rescue. Time to access a victim in a building is taken into consideration in the last step, similar to burial depth in an avalanche, but as a judgement not as a measurement since there are so many variables that will affect it. One being the time it takes for a team to get to the site (mode of travel, traffic, amount of equipment), which is more directly measured in avalanche rescue as distance between rescuer and buried subject. Finally, both environments make use of vital-sign data through high-tech devices. However, in wide-spread urban disasters triage, today's vital-sign technology for buried subjects in earthquakes are not applied in the first level selection of work-sites, as the application of the technology still is too time-consuming. Vital-sign data in earthquake rescue is only taken into account in the second level of triage.

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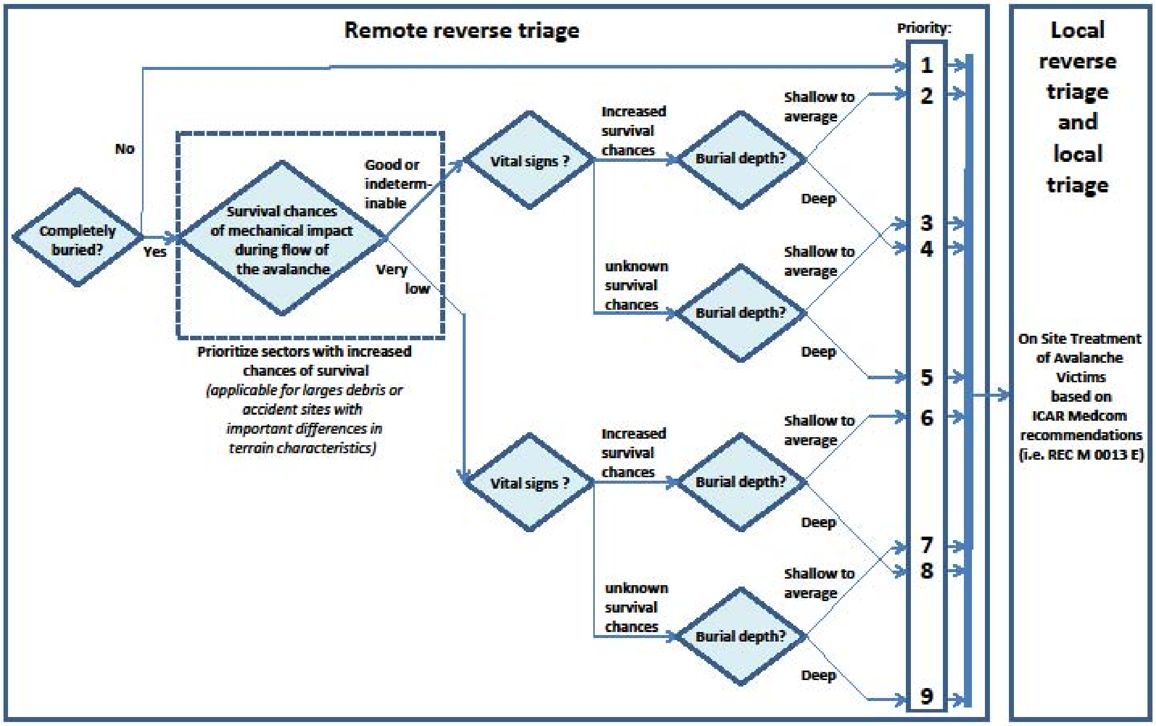

Fig. 6: Triage in avalanche rescue

Fig. 7: Triage in earthquake rescue