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THE SALVAGEABILITY OF DISASTER VICTIMS:
THE SCIENTIFIC BASIS FOR DISASTER PLANNING, RESCUE AND RESPONSE

Technological and conflict disasters present the 1980's with new and complex problems in preparation and response. Despite the increasing threat, the care of mass casualties remains a neglected area of applied research and technology. The reasons for this neglect are multiple -- psychologic ignorance, pride, guilt, and, perhaps, an untested belief that disaster victims are largely unsalvageable and that neither preparedness nor rescue are feasible.

This myth exists despite the progress critical care and traumatological surgery have made in the salvage of the massive multisystem injury victim. The inconsistency between our vaunted capability to salvage the individual victim injured on the highway and our seeming inability to cope with the same set of multiple injuries in individuals in a mass casualty demands examination.

Admittedly, the logistics of mass casualty care and the infrequency of such events in any one geographic region are intimidating and distracting. But the value of human life lost in mass casualty events is no less that of other accidents.

To explore the hypothesis that both research and a high level of rescue effort are useless, we decided to reconstruct a group of disparate disasters and their victims from the physical evidence of the events and from the hospital and autopsy records.

The goal of this study is to determine if all the victims of disaster who did die were irretrievably dead if we applied the same standards as we applied to study victims of a single highway accident. If they were not, was the nature of the pathology and the numbers of remotely salvageable victims such that a research program is justifiable within the cost and life effective standards of our society?

METHODOLOGY: Three disparate mass casualty producing disasters in three culturally, geographically, and economically different parts of the United States were selected: an earthquake in the suburban sunbelt area of Southern California, a volcanic eruption in the mountainous, fog-clouded area of the Northwest, and a rush hour air crash within the confines of a major East Coast city. Any, or all of these disaster types is likely to recur within the near future somewhere in the United States.

The circumstances of the calamitous events were analyzed from physical evidence, media accounts, and investigative agency reports.

Hospital and autopsy records were obtained for all victims. The individual medical records were analyzed for type(s) of injury, final cause of death cases, and potential survivability. The criteria for salvageability were those considered standard in the U.S. emergency system in 1983. Further analysis was made for patterns of injury and the overall potential for survival within each disaster, assuming optimum preparation and rescue. Trends have developed from the analysis of our data. However, rigorous statistical analysis will be presented in a subsequent report.

The analytic team consisted of a pathologist, forensic scientist, traumatologist, and critical care specialist.

RESULTS AND DISCUSSION

Disaster I: San Fernando Valley Earthquake: The San Fernando Valley is an idyllic area of sunny Southern California which extends roughly parallel to the Pacific coast. It is populated by moderate-sized suburban towns, well-to-do bedroom communities, and is additionally distinguished by its proximity to both the San Gabriel and San Andreas Faults. The area is also the home of Dr. Charles F. Richter on whose scale a modest quake of 6.2 occurred at forty seven seconds past six a.m. on February 9, 1971.

This became a mass casualty event largely because two hospitals containing nearly 800 partially immobile patients had been built adjacent to the known fault line. Both these buildings collapsed. Simultaneously all lines of access, rail and highway, to the damage site were fractured and became unusable.

Patterns of Injury: The cause of injury pattern was almost universally the result of patients being struck by or trapped in the prone or supine position by elements of the collapsing buildings.

The medical pattern of individual injury was consistent with the circumstances. Ventilatory failure, secondary to mechanical chest injury, predominated. This particular pattern of injury was a result of the occurrence of the quake during sleeping hours and the large number of bedridden patients. At midday a much higher incidence of head injury might be anticipated. (Table 1)

Fifty-six people died in this calamity. (Figure 1) The death rate would have been much higher, but a temporary Army Corps of Engineers construction site had been established in the mountains to the east. Heavy construction equipment for the extrication of victims was brought in within an hour across country without requiring access to the impassable highway system.

The predominate injury was mechanical chest cage injury. Forty-one, or 73 per cent were potentially salvageable under ideal conditions. (Figure 2) Over half of the possible survivors were amenable to treatment with an endotracheal tube and positive pressure oxygen by hand or mechanical means.

Lessons Learned: The lessons to be learned from this example are almost self evident.

1. Adequate, advance hazard assessment is essential in any area. Multistory hospitals constructed on known fault lines in rural and suburban areas invite casualties.

2. In an active earthquake area, the presence of immobile patients requires more adequate escape routes than are found in standard hospital building plans.

3. It must be anticipated that access routes may be blocked by earthquakes and heavy extrication equipment, such as tractors, bulldozers, winches, and hydraulic jacks, should be safely stored and the local maintenance staff trained in its use.

4. Adequate intubation and manual ventilatory equipment should be stored preferably in multiple sites.

5. The need for the development of more portable, durable ventilatory equipment has been demonstrated. (The advent of electromechanical chips that can act as near microscopic, highly reliable, inexpensive pressure, volume, and gas analysis sensors has opened a whole new avenue of portable bioengineering.)

Disaster II: Mount St. Helens: Off the shore of the Vancouver area of Canada and the Pacific Northwest of the United States, the small Juan de Fuca tectonic plate creeps under the coast of the North American continent at more than three centimeters a year. Rock melting into pockets of magma are reported to move horizontally into a necklace of volcanoes rising as high as 84 kilometers. Reaching the surface, ash and gases (carbon dioxide, ammonia, and sulfur based gases) explode into the atmosphere with the power, as in the case of Mount St. Helens, of a 5,000 megaton bomb. Lava flows, mud flows, and a 5.0 earthquake resulted. [1]

By March 21, 1981 the eruption predicted for the twentieth century by Crandell and Mullineu in 1831 had begun with the onset of preliminary quakes.[2] On May 18 the lava bubble burst through the crater top and out the north face. The event is, in a sense, a disaster preparation success. By denying thousands of recreationists access to the immediate area, government officials saved as many lives. Nevertheless, 23 people died.

Examination of the environment and the physical evidence of the death scenes along with the autopsy records reveals a great deal about the prevention of injury and the protection of rescue workers. People can be evacuated from blast, lava flow, deadly thermal energy and secondary flood areas. However, volcanoes hurl lethal, but potentially survivable ash or silica particles beyond these areas. These are the same particles which in small, chronic inhalations cause silicosis. Wilcox, in his monumental 1959 study of Alaskan volcanic ash falls, points out that toxic gases are rapidly dissipated at high altitudes,[3] although the Laki Fissure eruption in Iceland in 1783 reportedly produced a seven month fog of sulfur dioxide throughout much of Europe.[4] Wilcox also predictively indicted silica ash as the lethal agent whose effect extends kilometers beyond the blast blowdown, avalance, and mud flow zones.

Impacting tectonic plates, as opposed to separating plates, produce a larger percentage of lethal silica[5]. Baxter et al relate extraordinary cases of toxic gas deaths from the Javan Dieng volcano, the twenty-five year degasing cycle of Nicaragua's low lying Masaya volcano, and warn of the future possibility of toxic gases from the low lying vents of Mount Shasta.

Our reconstruction from reports, videotapes, photos of the scene, and ash analysis results supports the findings of Eisele and his colleagues[6] that particulate silica ash was the chief lethal agent in the unevacuated victims at the periphery of Mount St. Helens damage zone and the chief cause of failure of escape and rescue vehicles.

The reports of Baxter and his associates from the Center for Disease Control[5] and the Bulletins of the Federal Emergency Management Agency[7] suggest many lessons to be learned. Our reconstruction concurs.

Patterns of Injury: At Mount St. Helens, the gases were dissipated in the atmosphere and the 5.0 earthquake was limited to the immediate area. This is often the case in volcanism resulting from impacting rather than separating plates. The potentially damaging agents were heat, blast, and ash.

Only the lethal silica ash traveled far enough to produce a distinct pattern of injury causation. Mount St. Helens is a case study in successful hazard assessment, evacuation, and quarantine of the danger area.

The pattern of human injury was remarkably consistent. (Table 2 and Figure 3) Small silica particles at various temperatures were inhaled. These produced ventilatory failure secondary to tracheobronchial obstruction, due either to damage to the mucosal lining of the tracheobronchial tree or, in the worst cases, to the formation of completely occlusive tracheobronchial plugs of particulate matter and reactive mucous. The prevailing winds and the distance from the volcano determined whether pathology was limited to the mucosal lining or progressed to a fully obstructive silica and mucous plug. The additional effect of thermal injury on this process and its contribution to the lethality of the ash appears to depend on the distance of the victim from the sourch of eruption and the elapsed time. The ash also irritated the cornea and sclera, further impairing the victims' attempts to escape.

Of those 23 who did die, 17 died of asphyxia secondary to mechanical obstruction. These deaths might have been prevented by the use of industrial masks which incorporate eye protection and are readily available and inexpensive. (Figure 4)

<u>Lessons Learned</u>:

1. Hazard assessment and updated intelligence do provide the predictive basis for evacuation and perimeter policing in the case of volcanic eruption, which is a largely forseeable disaster.

2. Hazard assessment should include seismic monitoring, emergency ash analysis stations, and emergency air monitoring stations.

3. Local physicians and other hospital personnel should be educated in the management of acute silica inhalation and ventilatory failure. Local and reinforcing health facilities should be alerted to prepare for mass trauma casualties.

4. Area residents, rescue, and clean-up workers should be provided with the low cost, high efficiency goggles and masks now available. This equipment should also be deployed in advance in appropriate areas.

5. Trauma centers should be evaluated and designated in advance.

6. Individuals who are at risk by their proximity to a potential or actual volcanic eruption require a motorized means of transportation equipped with air filters. Electrolytic filters would seem to be the most practical at this time.

Disaster III: Air Florida 90 Crash: The heavy air traffic at Washington D.C.'s National Airport transports many policy makers, global scholars, and other VIP's. The area is subject to short, but fierce, winter storms and the Potomac River under the flight path is commonly frozen during these storms.

On January 13, 1982 the capitol city of the United States experienced just such a predicted storm. The city was partially paralyzed. The Potomac River which separates National Airport and Washington was frozen. The trans-Potomac bridges between the heart of the city and its suburbs were crowded with early rush hour traffic at 4:01 p.m. Within less than an hour the storm resulted in multiple urban auto crashes, a subway train crash, and the crash of a scheduled airliner whose aerodynamics were significantly impaired by the accumulation of ice.

On board were seventy-two passengers and five crew members. The aircraft acceleration was insufficient to achieve the essential initial velocity. The flight, however, was not aborted. It lost altitude, struck the Fourteenth Street Bridge and destroyed seven vehicles killing four occupants. Evidence indicates that as it hit the bridge the fuselage was close to the attitude it would have at rest on the field. The plane then passed through the railing of the bridge and struck the ice-covered water at a 25 to 30 degree pitch, nose first. The cabin separated from the cockpit and fractured into three fragments.

The investigatory National Transportation Safety Board concluded that the "probable cause of this accident was the flight crew's failure to use engine anti-ice during ground operation and takeoff, their decision to take off with snow/ice on the air foil surfaces . . . and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings . . . The inherent pitchup characteristics of the B-373 aircraft . . . and the captain's failure to reject the takeoff during the early stage when his attention was called to it probably contributed to the accident."[8]

Of the 77 passengers and crew aboard, five survived.

Patterns of Injury: The pattern of injury causation was not that of rapid deceleration and sudden death.

There are three criteria for survival in an airplane crash:

1. The decelerative forces must not exceed the known tolerable limits of the human body. Evidence indicates that the primary impact forces experienced by the passengers did not exceed those limits.

2. The restraint system (seat belt, seat structure, and seat anchorage) must remain intact. This criterion was not met.

3. The passenger occupied space must remian inviolate. This also was not met.

A further impediment to survival was the inability of mobile survivors to retrieve or open the plastic package containing flotation vests. Those packages which were open had been torn apart by the survivors' teeth.

The injuries were the result of secondary impact caused by the failure of the seats to remain fixed to the floor and design failures in the fuselage. Collapsing cabin walls and floor, contents of the overhead baggage bins, and flying metal seat backs resulted in multisystem trauma. Victims were trapped by incursion of the unsafe fuselage structure on cabin space which should be inviolate in any crash. There were no surface rescue boats and personnel designed to extricate the passengers from their metal prison. The water temperature at four feet below the surface was 34 degrees F. NASA data indicates this temperature would have caused unconsciousness in at least 50 per cent of the survivors within twenty minutes. If the passengers were not unconscious they were mechanically trapped and paralyzed by hypothermia. The only possible access would have been by trained rescue swimmers with extrication gear.

Had they been retrieved, our reconstruction indicates that between 18 and 26 (Figure 5) were salvageable by modern medical techniques and would have survived. This was substantially in agreement with the findings of the National Transportation Safety Board. We arrived at these conclusions by eliminating all of the severe head injuries, cervical spine injuries and a complete transection of the aorta. Again we applied our judgemental criteria as we would in an emergency room setting. The remaining injuries consisted of the usual array of thoracic, abdominal, and long bone trauma and other conditions remediable in our Level I trauma centers.

Lessons Learned:

1. The myth that all large passenger air craft crashes are totally and irretrievably fatal is unsubstantiated.

2. Aircraft may crash at deceleration G's which permit survivability and should be designed to allow passenger escape.

3. The nagging problem of seat design and seat position has never been fully confronted by the aircraft industry and is compounded by current near capacity loads.

4. Passenger instruction in the use of and the design of escape and flotation gear is grossly inadequate.

5. Hazards change with weather conditions, human attitudes, and other ephemera. Emergency equipment and training should be sufficiently flexible to respond to changing conditions. This is the responsibility of emergency medical services command.

6. Medical personnel and hospital units should be apprised of the increasing and decreasing probabilities of air crash as a result of weather, load, and seasonal changes. They should be trained to cope with such exceptional conditions as hypothermia complicating traumatic injury, combined hypo and hyperthermia with traumatic injuries, and other uncommon diseases. Real time data banks and consultative advice should be available and easily accessible.

CONCLUSIONS

Local hazards and the probability of disaster occurrence are often predictable. Adequate regional hazard assessment would permit the development of specific, applicable training programs for medical and rescue personnel as well as the appropriate deployment of equipment in advance of a calamity. These assessments must be modified on a timely basis as conditions change.

The patterns of causation of injury are often consistent thus permitting adequate preparation.

The patterns of injury are also fairly consistent and should set the model for training and the deployment of equipment.

An appropriate research and development program is necessary to determine actual rather than assumed patterns of injury and thus providing a basis for cost effective training and the development and deployment of equipment specifically designed for rescue and for simultaneous extrication and life support.

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Please note:

This is a preliminary report of a long standing investigation into the patterns of destruction and injury in specific mass casualty situations which was conducted with the support and assistance of the United States Federal Emergency Management Agency. This report represents the views of the authors and not those of the United States Government or any of its Agencies, the Georgetown Center for Strategic and International Studies, the University of Arizona or the George Washington University School of Medicine.

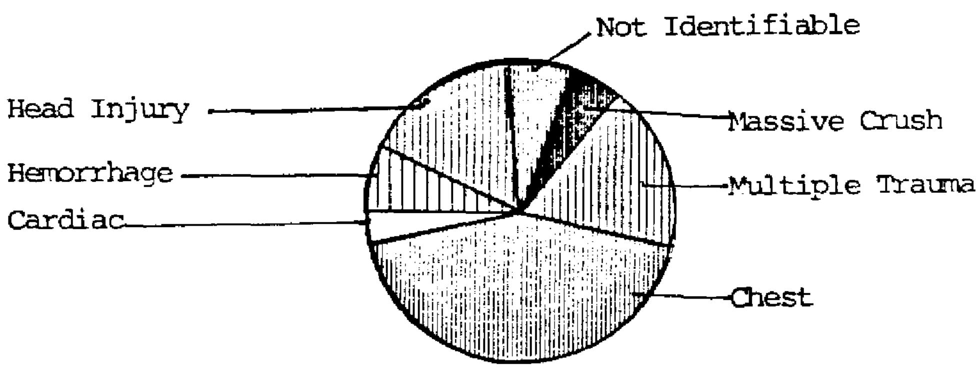
For reprints, write: Dr. Martin E. Silverstein, CSIS, 1800 K St. NW, Washington, DC 20006

Table 1

CAUSES OF DEATH SAN FERNANDO VALLEY EARTHQUAKE

Thoracic Cage Injury	24
Multiple Trauma	10
Head Injury	9
Hemorrhage	4
Unidentifiable	4
Massive Crush	3
Cardiac	2
Total	56

SAN FERNANDO VALLEY EARTHQUAKE



SAN FERNANDO VALLEY

EARTHQUAKE

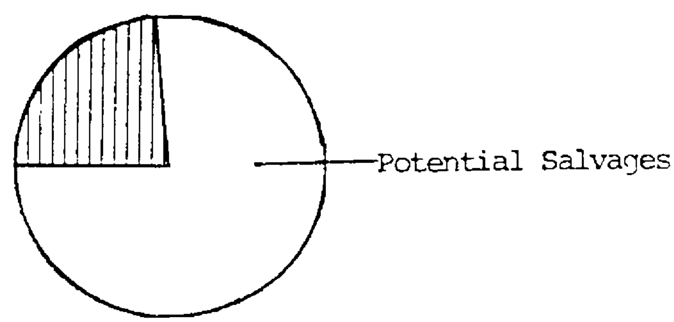
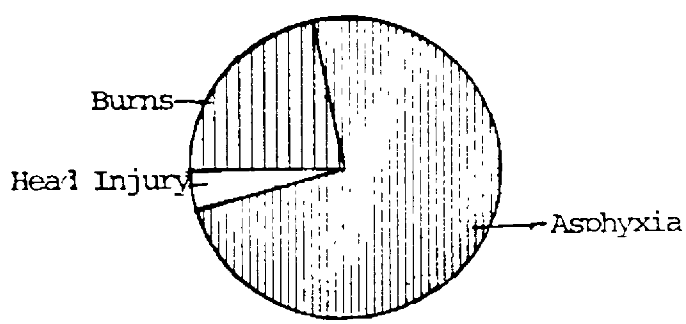


Table 2

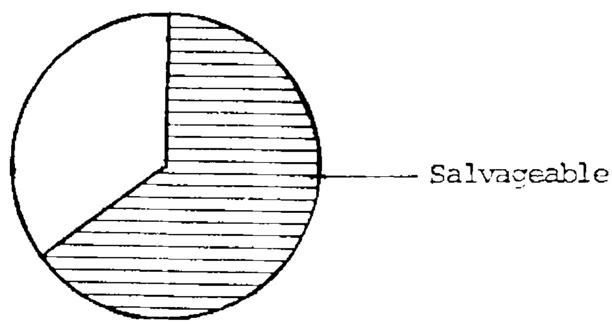
CAUSES OF DEATH MOUNT ST. HELENS ERUPTION

Ventilatory Failure	17
Burns	5
Head Injury	1

MOUNT ST. HELENS



MOUNT ST. HELENS



AIR FLORIDA CRASH