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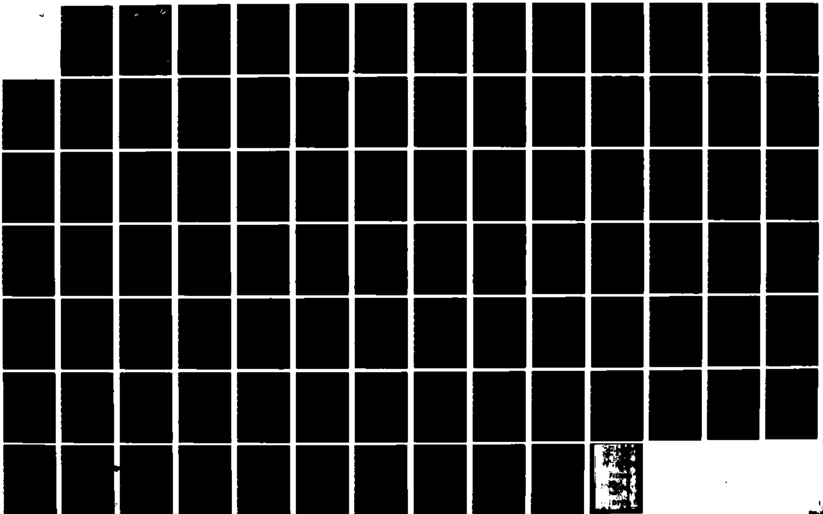

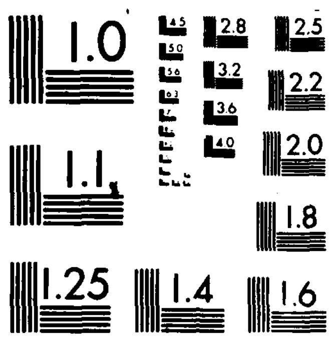


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TRIAGE DECISION TREES AND TRIAGE PROTOCOLS

CHANGING STRATEGIES FOR MEDICAL RESCUE
IN CIVILIAN MASS CASUALTY SITUATIONS

FINAL REPORT

for

FEDERAL EMERGENCY MANAGEMENT AGENCY
WASHINGTON, D.C. 20472

FEMA CONTRACT NUMBER EMW-C-1202

FEMA WORK UNIT NUMBER 2412G

February 1984





APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

# TRIAGE DECISION TREES AND TRIAGE PROTOCOLS

## CHANGING STRATEGIES FOR MEDICAL RESCUE IN CIVILIAN MASS CASUALTY SITUATIONS

by
Martin Elliot Silverstein, M.D.

THE GEORGETOWN UNIVERSITY
CENTER FOR STRATEGIC AND INTERNATIONAL STUDIES
1800 K Street, N.W.
Washington, D.C. 20006

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report addresses the state of the art of the decision-making process and the technology of disaster victim rescue. A technique of disaster reconstruction based on autopsy reports and physical evidence is utilized to determine the potential survivability under improved or optimum conditions. The report concludes that advanced technological preparation based on scientific hazard assessment and state of the art of disaster medicine would significantly increase survivability.

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## SUMMARY

The objective of this study is to determine whether improvements can be made in the disaster rescue process in order to increase the survival of victims who now die. In addition to a review of the available literature on the triage decision process the investigation reviewed over one hundred disasters and attempted to "reconstruct" several disparate disasters from autopsy reports and other evidence.

The report includes a description of the state of the art of civilian disaster triage and medical rescue. Disaster medical procedures are contrasted with the much more advanced state of the art of trauma care in general.

The essential findings of the study are that:

- there is a multidecade gap between the state of the art of civilian disaster medical rescue including triage formulae and present levels of trauma care in the United States;
- there is evidence that a significant percentage of victims who die in disasters could be saved by improved medical rescue techniques and disaster management strategy;
- a set of recommendations to close this gap are derived and presented herein.

TRIAGE DECISION TREES AND TRIAGE PROTOCOLS

CHANGING STRATEGIES FOR MEDICAL RESCUE IN CIVILIAN MASS CASUALTY SITUATIONS

## PREFACE

**THE ETHICS OF TRIAGE** Many decisions made in preparation for the response to disaster hold the potential for life and death of the victims. No node in the process so clearly requires the disaster manager to give the resourcs of life or withhold them as do those decisions subsumed in the "triage" process. The ethics of such decision making underlies all investigation into the process. Thomas J. O'Donnell, S.J. has explored the problem and concludes "the need for such sorting is ... indicated from the viewpoint of the exigencies of the Natural and Divine Positive Law. Current military and medical considerations are ... in accord with proper ethical and moral principles." (143)

## PROJECT OBJECTIVES

To examine the relevant medical and disaster literature in order to determine the state of the art and particularly the triage node of the disaster response system. The literature and data base search was planned to establish a base line evaluation of medical rescue, to provide relevant information on a large number of disasters and to avoid the duplication in so far as possible of existing disaster procedure guidance documents.

To review from documentary sources a large number of disasters and disaster victims in an effort to determine the availability of demographic, physical, and forensic data in conventional disaster literature.

To obtain and examine in detail the autopsy records and accounts of physical evidence of fatalities in the light of present day optimum disaster management.

To determine the availability and quality of such records as a source of information from which to derive an analysis of the destructive and rescue process.

To "reconstruct" those disasters from truly evidentiary material in an effort to determine whether a present day and/or superior process would have resulted in a greater salvage of lives.

To determine, in effect, whether under model conditions all who died were doomed under any circumstances.

To consider what measures, decisional and otherwise, can be taken to save the potentially salvageable but currently unsalvaged victims.

## METHODOLOGY

An extensive literature search was conducted through the mechanisms of the National Library of Medicine, the Library of Congress, the Federal Emergency Management Agency's collection of documents and audiovisual materials. The Medical and Main University Libraries of Georgetown University, George Washington University and the University of Arizona and their reference staffs assisted in the search for literature and documents.

Data base search was amplified by computer examination of Lockheed's Dialog data bases conducted by consultant Dr. M.A. Cremer.

The Italian literature in reference to contemporary Italian disasters and, particularly, the extensive print and electronic media coverage of the earthquake of 1980 was conducted and translated by Professor Gianni Spera of the Romance Language Department of the University of Arizona and Mrs. Claire Spera of the Arizona Press, Inc. and their staffs. Several hundred newspaper articles and transcriptions were examined and translated.

The librarians of the Washington Post and the Los Angeles Times provided reproductions of documents and information.

The facilities of the Georgetown University Center for Strategic and International Studies made possible numerous and lengthy interviews with experts on decision making and crisis management. The opportunity for the Principal Investigator to participate in Mr. James Woolsey's crisis management conferences provided access to an exchange of information on crisis decision making in areas of vulnerability in such areas as the military, energy, information systems, and transportation.

Face to face interviews were conducted with Dr. Franco Ferracuti, Professor of Criminology and Forensic Psychiatry of the University of Rome, Professor Carlo Manni, Professor of Surgery, Catholic University of Rome, Dr. William Gunn, Director of Emergency Service, World Health Organization, Dr. Nicholas de Feu, Professor of Emergency Medicine, Henri Mondor Medical

Division of the University of Paris supplied documentation regarding the curriculum of the School of Disaster Medicine, Dr. P. Hugenard, Professor and Head of Department of Anesthesiology and Reanimation and Head of the School of Disaster Medicine of the Henri Mondor Division of the University of Paris, Assistant Professor Patrick Laguedec of the Ecole Polytechnique provided over thirty-two documents dealing with disaster planning and management and several interviews. Dr. David Nancekievill of St. Bartholomew's Hospital in London contributed several days of interviews concerning his experience with and conduct of triage in close to 4000 major accidents and disasters. Dr. William Fahey of New Zealand, described his forensic experiences in the examination of Antarctic disaster sites. Dr. Victor Esch of the District of Columbia Police Fire Surgeons and Miss Myra Lee provided eye witness accounts of the Air Florida 90 crash and the Mount St. Helens eruption respectively.

Dr. Donald D. Trunkey, Chairman of the Committee on Trauma of the Amercian College of Surgeons and Professor of Surgery, University of California at San Francisco, not only contributed in several face to face interviews but obtained the interest and cooperation of the 25 members of that committee and the State Chairmen of the fifty states' Trauma Committees. Dr. Frank Mitchell, Professor of S rgery, University of Missouri and head of the Disaster committee of the ACS COT, provided his wisdom, his analytical thinking and his thoughts on the new Madrid earthquake to come. Dr. E. Ott and Dr. E. Martin described the Munich rescue vehicles and changes in their system occasioned by the Oktoberfest bombing.

Three very different mass casualty producing disasters in three culturally, geographically, and economically different areas 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.

Hospital and autopsy records were obtained for all but three of the victims. The individual records were analyzed for type(s) of injury, cause of death, and whether or not this patient might have survived given optimum care. The criteria for salvageability were those considered standard in emergency rooms and operating rooms in 1983. Medical records vary and in some cases the correct decision was not clear. In those cases we classified the death as unpreventable. Further analysis was made for patterns of injury and the potential for survival within each disaster. Definite trends have developed from the analysis of our data.

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

As anticipated, obtaining actual autopsy records was a major task during the course of the study for many reasons, not the least of which was local agency reluctance to disclose these records on an anonymous research basis. In the long run the task would have been difficult, if not impossible, had not the Principal Investigator and Dr. Cornelius G. McWright, Former

Chief of Research of the FBI been able to fall back on the credibility and dependability of long term relationships. Dr. James Luke, former Chief Medical Examiner of the District of Columbia, was of inestimable help. Dr. Richard C. Froede, emerged as the chief consulting forensic pathologist. He succeeded in obtaining the detailed documentation of one of the disasters studied in detail and participated energetically in the analysis of data and was the chief architect in the development of the "Disaster Research Autopsy Protocol" concept leveloped in this report.

NASA provided satellite and overflight views ' the three disaster sites which formed the basis of our study of the geography of the disaster areas.

## DISCUSSION OF RESEARCH ACCOMPLISHED

## PART I

### HISTORICAL PERSPECTIVE

The historical evolution of the simplistic label "triage" for a constantly evolving process which now represents the prioritization based on balancing pathophysiological needs with available medical skills. Materials may be found in its history and explains much of the oversimplification and misunderstanding found in our times.

Originally a french noun, "a triage", a place for sorting military casualties, is derived from the french "trier" which was the french and later the english process of dividing wool fibers into grades of quality and usefulness. Its origin as a medical term is unclear. The Oxford Dictionary makes no mention of triage as a medical term. There is a suspicion that the process was introduced into military medicine by Baron Dominique Jean de Larrey (1766-1842), Napoleon's brilliant and innovative battlefield surgeon. Larrey's epochal work emphasized the salvage and early recovery of wounded soldiers so that they could be considered skilled reinforcements and the invention of the rapid battlefield ambulance lends credence to this thought.

An analytic approach to the relationship of patterns of injury to the medical organization of the Prussian Army's 1866 and 1870 campaigns was attempted (75). The implication of gunshot wounds as opposed to those inflicted by the lance and the saber was clearly identified.

Accounts of American civil war surgery suggest knowledge of sorting. Since truncal, cavitary wounds and multiple injuries were unsalvageable, triage consisted of the obvious process of separating those wounded from manageable or amputatable limb injuries.

It is established that "the triage" as a place and a concept in the American Expeditionary Force of World War I was apparently borrowed from our French and British allies. Triage represented a distribution point from whence wounded were sent to appropriate hospitals (124).

The latter half of World War II saw the introduction of a sophisticated divisional hierarchal medical structure based on the severity of injury and available skills and materials. For all practical purposes this represented the first systematic organizational triage based on matching wound configuration and severity to medical capability.

The United Nations' forces in Korea brought to fruition an understanding of secondary organ deterioration as a result of shock and infection suggested in World War I. The relationship of triage to rapid transportation begun in the Napoleonic wars introduced another factor into the now complex triage algorithm. Surgical capability permitting the repair of major blood vessel injuries changed the time table of triage decisions.

The significance of medical communication, rapid communication, air mobility, and further knowledge of the need for secondary organ support and the introduction of lessons from critical care medicine translated into life support techniques became important factors in triage during the war in Vietnam. Oddly enough, the unusual combination of massive avialability of air evacuation and a peninsular war may have simplified the triage process. The matching of resources to pathophysiological needs in the Vietnamese War produced an American record in the salvage of military lives.

Medical rescue in this recent war underscores the difference between contemporary civilian disaster situations and military triage. In general, military planners can and should anticipate the expected configurations of wounds and numbers of casualties and are able to emplace matching medical resources.

This is generally not the rule in civilian disasters. There is no identifiable battlefront where casualties can be expected to occur. Civilian disasters may occur anywhere and anytime within the nation's boundaries. The nature of the disaster and hence the type of injuries have a much broader spectrum. The allocatable resources are usually not emplaced with the same orderliness or availability of the military system.

For these reasons military triage methodologies cannot be transferred to the civilian arena without considerable modification.

## CONTEMPORARY TRENDS IN THE DEVELOPMENT OF TRIAGE DECISION MAKING METHODOLOGIES

### The Influence of Military Procedures

Because of this lack of uniformity and preparation of civilian disaster resources and because new and more frequent disasters have become a major concern of medical community leaders considerable research into the triage process has occurred in the last few years. At first glance, the literature would appear chaotic. There are, however, clearly discernable, if not clearly *reconcilible trends*. It is evident that recommended triage methodologies are highly dependent on each expert's view of the larger disaster management strategy. The designers of recommended triage systems often reflect their own special experience in a single disaster or indicate a lack of awareness of the variability of civilian disaster situations and the multiple, alternative strategies which may be required. There is a distinct danger in formulating triage methodologies in a strategic vacuum. Preparation for the wrong disaster situation can be as costly as military preparation for the wrong enemy on the wrong terrain.

The basic template of the triage process must be amplified and modified by:

- the specific purpose of the sorting process;

- the echelon in the hierarchy of medical response in which triage is to be performed;
- the level of skill and the available resources of the triage personnel.

The simplest category of triage systems are those which identify the victims who are not doomed under any circumstances by their initial injury but do require some level of care. These systems such as that recommended by Hunt of the University of California (102) divide patients according to the level of medical skill which they require, thus also indicating but not describing the distribution and disposition. An example is provided in the NATO Handbook, "Emergency War Surgery" (65):

I Slight injuries which can be managed by self help or by nurses and technicians

II Injuries which require medical care but which can be managed at least partially by paramedical personnel

III Injuries which require major surgical management either (a) without delay (b) with delay for resuscitation, or (c) with delay commensurate with further study and the needs of the patient

IV Injuries which are beyond repair

In this same category are simple systems designed to sort victims by transportation needs. One classic example:

I Ambulatory, no immediate care needed

II Ambulatory, delayed care acceptable

III Requiring immediate care on site

IV Urgently requiring hospital level care

V Deceased or unsalvageable

The familiar tagging system promulgated by Bowers and Hughes (17) prioritizes for transportation and distribution based on need and expected outcome.

I Green Tag -- Casualties requiring minimal treatment as outpatients or requiring domiciliary care.

II Red Tag -- Casualties requiring immediate treatment and whose chances of recovery are good after immediate definitive care.

III Yellow Tag -- Casualties requiring treatment but who could tolerate delay, with chances of recovery considered good after definitive care.

IV Blue Tag -- Casualties requiring expectant treatment with poor chances of recovery because of the magnitude of the injury and/or because an excessive committment of personnel and material would be required.

These systems have the virtue of simplicity. They represent little progess since the inception of military triage incorporating none of the advances in communications, transportation, rescue, and field application of critical care techniques. Rigourously examined they imply a high level of medical diagnostic acuity. They are too generalized to offer guidance in planning for specific disasters or in allocating resources in the initial phase of disaster response. These classifications are of little assistance during the frantic initial rescue, extrication and life support efforts.

The Six Day War in the Middle East presents for study an extraordinary amalgam of military and civilian medical systems combining to provide a medical disaster response. The valuable documentation (138, 142) of Israeli procedures emphasizes the complexity and importance of the initial rescue period while demonstrating the utility of persistent redistribution triage which makes each echelon of care which the patient reaches a triage and transportation point. This process is continued until the patient reaches a facility which has the resources to definitely cope with the victims' injuries.

The most critical decision making takes place at the site of the disaster. It is during the simultaneous process of immediate rescue, extrication, and the provision of life support that triage is most critical and most difficult. Rapid diagnostic evaluation and allocation of life support resources is the essence of optimal salvage.

TRENDS GENERATED BY APPLIED TRAUMA RESEARCH

The strategy of disaster management cannot incorporate advances in communication, transportation, hazard assessment and prediction and ignore those advances in medicine made since World War II and which have the potentiality for saving the lives of casualties. Those advances lie in two broad categories of medical care:

- The intrahospital anesthetic, operative and postsurgical methodologies which allow the life saving repair of major multiple injuries to vital organ systems, skeletal structure, and the vascular system on which they are dependent.

- The prehospital techniques for the maintenance of the support infrastructure of the vital organ systems of the human organism which stave off death until the victim can reach the major hospital milieu in which the specific organ system repair is available.

These subsets of clinical and research medical activity actually intersect extensively. Progress in surgical instrumentation and techniques could not have occurred without parallel advances in diagnostic radiological and other imaging modalities and achievements in biochemistry, immunology, microbiology and molecular biology. Specific advances in the physiology and technology of vascular and neurosurgery have contributed heavily. But, the intrahospital salvage of the patient would be totally impossible without the anesthetic and postoperative applications derived from the physiology of so-called intensive care. Slowly, but relentlessly, profound hemorrhage, subsequent shock, burns, external organ damage, infection, immunoconsumption, and the interactive posttraumatic multiple failures of kidney, liver, lung and other organ systems have ceased to be inevitable causes of death.

The basic knowledge and the techniques of what is known in American hospitals as intensive care and in most European hospitals as reanimation have their most recent origins in the post World War II era and have been growing exponentially over the last two decades. Their impact has been greatest on the cardiac, bacteriologically infected, and trauma patients.

Reanimation or life support consists of methods of maintaining an airway with such devices as an endotracheal tube. Respiration is carried on for the patient through a bladder and valve system or by a completely automated system. The cardiovascular support is maintained by replenishing the blood volume intravenously and assisting the heart pharmacologically.

## PRIORITIZATION STRATEGIES BASED ON PREHOSPITAL SUPPORT AND INTRAHOSPITAL REPAIR AND RECOVERY

Although the rescue and medical management systems for the victims of mass casualty events have yet to be fully devised and adopted, analagous mechansims have been developed and proven their worth in the survival of individual trauma victims. Applicable triage and other decisional strategies have advanced along this route (although the exigencies of mass rescue are not a consideration in the treatment of endemic trauma).

A notable advance in combining true triage decisions with life support techniques was made by the Committee on Trauma of the American College of Surgeons in the course of the laborious construction of the Advanced Trauma Life Support curriculum (ATLS) (49).

The "*initial assessment*" procedure and treatment scheme of that short course offered to surgeons, emergency physicians and other urgent care specialists is an example of a methodology designed to respond to this extraordinarily difficult problem. It outlines and combines assessment and prioritization with life support management options. Implicit in the procedures recommeneded is a triage decision scheme which has been constructed by us as follows:

I Victims with minor injuries who are able to extricate themselves and leave the scene of the disaster unassisted

II Nonambulatory victims who require some form of extrication and nonurgent transportation but no life support

III Nonambulatory victims who require some form of extrication, no life support but urgent transportation to an appropriate hospital resource

IV Victims who require life support during or after extrication and urgent transportation

V Victims who require life support and urgent surgery at the site if immediate access to an appropriate hospital resource is not feasible

VI Irretrievable or inextricable victims who require relief from pain and appropriate psychological support

VII Inextricable victims who require no care and the deceased. These victims will require eventual extrication and identification and examination

The ATLS priorties for life support and urgent intermim care (49) which must accompany triage are:

1. Airway mantenance
2. Breathing including control of the respiratory pathways of the cervical spine
3. Circulation (Blood Volume) and Cardiac Pump Maintenance
4. External management of hemorrhage and shock
5. Fracture splinting
6. Continuous monitoring of vital signs
7. Further evaluation of injuries including level of consciousness.

## THE TREND TOWARD QUANTIFICATION

The same ATLS curriculum demonstrates one of the rough attempts at injury quantification as an input to decision making identified as "Field Categorization". It is based on the degree of injury to each of the anatomical systems modified by the level of vital signs. Only three categories are provided.

Included in the same curriculum is a more physiological scoring from 0 to 4 which is based on field clinical keys to physiological deterioration. This attempt to provide a numerical basis for triage decisions exemplifies a larger number of published efforts to lay a physiological and numerical basis for triage decisions.

| | | | Score |
|---|---|---|---|
| 1. | Measure "Capilliary Return" (in nail bed) | Normal | 2 |
| | | Delayed | 0 |
| 2. | Measure Respiratory Effort | Normal | 3 |
| | | Shallow | 1 |
| | | Retractive | 1 |
| | | None | 0 |
| 3. | Eye Opening | Spontaneous | 3 |
| | | To Voice | 2 |
| | | To Pain | 1 |
| | | None | 0 |
| 4. | Verbal Response | Oriented | 4 |
| | | Confused | 3 |
| | | Inappropriate Words | 2 |
| | | Incomprehensible Words | 1 |
| | | None | 0 |
| 5. | Motor Response | Obeys Command | 4 |
| | | Withdraws | 3 |
| | | Flexion | 2 |
| | | Extension | 1 |
| | | None | 0 |

Combined with an anatomical evaluation of injuries this scoring system provides a reasonable basis for initial triage decisions performed during the rescue process.

Severity scoring, a statistical basis for triage decisions derived from the observed injuries and altered physiology of the patient, has its practical origins in the remarkably effective pioneer work of Evans et al (66), Cope and Moore (52) and carried forward by Moncrief and Artz (4, 134) and brought to its present state of fruition by Generall Basil Pruitt of Brooke Army Medical Center. A simple calculation based on the depth of burn, percentage area of the body burned and body weight provided an accurate and what has proved to be an enduring index of the severity of the injury, the immediate therapy required, and the probability of outcome. Modified by factors for children and adults this calculation derived from the products of three numbers remains the state of the art of the basis for the triage of burns.

The past few years have seen the development of much more sophisticated and complex Severity Indices. Although in many cases they have demonstrated reliability of prediction, their increasing complexity makes them useful only at higher echelons of care than the immediate rescue effort.

The Triage Index (TI) whose statistical basis was developed by Hannan (90) as part of her Master's thesis and which has been developed clinically by Champion et al (45, 46, 47) bridges the gap between simplest statistical evaluations such as the ATLS example and those which include more statistical sophistication.

The sensible trend toward quantification has produced a variety of methodologies. Most are additive or represent the introduction of cluster analysis techniques. The Abbreviated Injury Scale (AIS) (50) provides a basis for studies in trauma epidemiology but is noteworthy as a model of ingenuity in that it can be used by individuals of varying levels of skill. The Injury Severity Score (ISS) developed by Baker, O'Neill and Hadon (5) provides the basis for evaluation of the care received by multiple injury patients. Understandably these methodologies are directed toward highway injuries and other endemic trauma.

Quantification for special situations and specific organ systems have also been developed. The Glascow Coma Scale (105) like many of these is a hospital "watch sheet" which has been adapted and incorporated into broader trauma scoring systems.

As might be expected, the wealth of quantification schemes published or in production has produced useful controversy and analysis (82, 113, 114). Valuable evaluations of the quantification process have been conducted by Hugenard (99) and by a panel chaired by Trunkey (175). Krischer (113, 114) is the severest critic of the statistical basis of severity quantification systems thus far advanced. His discussion of the conceptual development of the statistical basis for severity decisions should be consulted before one is adopted. Despite his objections, Baker and O'Neill (6) have demonstrated the outcome reliability of the Triage Index (TI) and the Injury Severtiy Scale (ISS).

BLACK BOX QUANTIFICATION

Minute by minute evaluation of the patient within the critical care unit has been developed by Siegal et al (161) among others. Siegel's sophisticated work is noteworthy in that its inputs are derived from eleven invasive cardiovascular and pulmonary physiological studies which are computer analyzed at the bedside. The work of Siegel and others hold promise for a "black box" quantification of the disaster victim at the hospital level.

The U.S. Navy has evolved an expert computer system to assist in military triage. This system would appear to have great promise for the future of civilian triage.

Silverstein, Franken and Small (166) have attempted to adapt the "black box" solution to a single automated portable noninvasive measure of cardiac output of Doppler analysis analagous in application and display configuration to a hand held electrician's digital voltmeter. A number of university laboratories have work in progress on noninvasive measures of cardiovascular status based on limb and organ perfusion. Since the evaluation of shock and impending shock represent what may be the most difficult single problem in triage, therapeutic, transportation, and disposition decisions, the need for a simple, portable instrument system to amplify such additive evaluations as the ATLS is urgent.

## TRIAGE BY ALGORITHM

Triage algorithms have grown in number and publication at the same rate that pseudocomputer logic and flow charting have become popular. While algorithmic rules are attractive on the printed page, Lindsey and Silverstein (121) reviewed trauma triage algorithms, collaborated in testing them in real life situations and then developed a decision algorithm which they felt included all of the decisional steps. It is their considered opinion that algorithms have a utility in the teaching of triage decisions but are too cumbersome to use in the time and place under which the rescue and teatment of mass casualties occur.

TREND TOWARD THE CONCENTRATION OF MEDICAL RESOURCES

The many advances in the care of the injured are resulting in organizational changes in medicine. Day to day emergencies are responded to by regional emergency medical systems. Hospitals have installed highly professional emergency medical departments. State of the art care of the injured demands specialized radiological and other diagnostic equipment, larger emergency departments, special operating rooms, surgical trauma specialists, and advanced intensive care units. The scarcity of these elements and the economic and organizational demands they require of the hospital have fostered a trend toward the concentration of the equipment and personnel required for trauma care in a single institution in each region. The development of this Regional Trauma Center Program is in progress across the country. Special interests in medical rescue are gravitating toward these centers. It appears logical that the Centers become the medical element in regional disaster management providing education, research, and clinical care, both within the institutional setting and as outreach toward disaster sites.

# PART II
# DISASTER CASE STUDIES

In the course of this study and previous studies by the disaster and crisis research group of the Georgetown University Center for Strategic and International Studies, a number of case studies have been reviewed in an effort to develop a broad understanding of the calamitous events to which civilization is susceptible. In this study we have reexamined those events in an effort to discern the elements which would lead to improvements in the salvage of lives. In order to identify a sufficient variety of representative catastrophes whose documentation contributes to an understanding of the casualty scene and the actual or potential rescue process a broad geographical and chronological framework was required.

Ordering and classifying of case material became a necessity.

## TAXONOMY

A taxonomy was developed based on the etiologic origin of the event rather than the numbers of casualties. This was deemed necessary because rescue is related to the circumstances and to the nature of injuries. Body counts of injured and dead provide only one dimension of the victim situation. In general, only acute disasters were investigated. Slow disasters such as drought, famine, and prolonged epidemic infectious disease, while presenting some common elements, did not include phenomena of rapid injury and the need for rescue.

The classification based on etiology divides disasters into three categories: natural, technological, and conflict. Each of these categories is subdivided according to the specific initiating situation. Natural disasters are thus subdivided into earthquakes, volcanos, floods, hurricanes, etc. Technological disasters, which are very much on the increase, include urban fire, industrial explosions, nuclear accidents, release of hazardous materials into the atmosphere as a result of air crashes, surface transportation accidents, etc. and societal disruption as a result of major loss of energy supply, transportation or information systems. Under the major category of conflict is subsumed riots, terrorist acts, such bizarre events as the Jonestown mass death as well as the civilian calamaties secondary to declared and undeclared warfare. Specific events were then further divided according to numbers of casualties, the ratio of casualty needs to resources and the potential sociopolitical disruption with its psychological trauma to citizens.

## GENERAL CASE SURVEY

Events whose general characteristics were surveyed in order to test the validity and utility of this taxonomy include:

| Natural | Technological | Conflict |
|---|---|---|
| Galveston Flood<br>1900 | Chicago Theater Fire<br>1903 500 casualties | Luisitania Sinking<br>1000 casualties |
| Sicily Earthquake<br>1908<br>100,000 casualties | SS General Slocum<br>1904<br>Steamboat Fire | SS Mont Blanc<br>Munition ship explosion<br>1000 casualties |

Ohio Ind. Flood
1913
3000 casualties

Tornado Illinois
1925
3600 casualties

Hurricane Carribean
1926
650 casualties

Tornado St. Louis
1927
669 casualties

Southeast U.S.
Hurricane
1928
400 casualties

Naples Earthquake
1930
639 casualties

Baluchistan
Earthquake 1935
20,000 casualties

Florida Hurricane
1935
200 Casualties

12 State Flood
1936

Cherry, Ill. Mine
Cave-in 1909
400 casualties

Titanic Sinking
1912
1250 Casualties

SS Empress of Ireland
Sunk in Fog 1914
954 casualties

Salem, Mass. Fire
1914

ZR2 Airship Explosion
London
1921
33 casualties

Oppau, Germany 1921
Industrial Explosion
3000 casualties

St. Francis Dam Collapse
Los Angeles 1928
974 casualties

Cleveland Clinic
Toxic Gas 1929
100 casualties

U.S. Airship Akron
1933
73 casualties

Ohio Prison Fire
& Riot 1930
335 casualties

Civil Disturbance
in Brazil 1930

Striker-Police
New York City

Mosely Police Riot
London 1961

Kennedy Assassination
1963
Dallas*

Airliner Machine-
gunned, Zurich 1969
6 casualties

Marks & Spenser
stores firebombed
London 1969

Airport bus grenade
Munich 1970
13 casualties

Mid-air bomb
Zurich 1970
47 casualties

* The injury or death of a single individual may, under certain circumstances, threaten the fabric of a society (See Glossary definition of disaster).

The differing characteristics of the three major categories and their generally, but not constant, proportional relationship to casualty numbers and types of injuries convinced us that this is a useful taxonomy. Natural disasters tend to begin less abruptly, provide warnings sufficient to mobilize rescue forces and are generally geographically wide spread. Technological disasters are abrupt, urban, and are dominated by fire and the need for extrication from buildings. Conflict events produce significantly lower levels of casualties with a wider range of public attention and disproportionate impact on the politico-social structure. Both technological and conflict situations tend to occur in intelligence anticipatable vicinities allowing rescue team preparation and advance deployment of rescue resources. Communication, transportation, hospital resources, police and firefighters are emplaced; and alternate, expectant scenarios can be developed. Specific injuries are predictable in all categories.

## SELECTED CASES FOR STUDY

A closer review of a second set of disasters confirmed our general impressions.

| Disaster | Type | Casualties | |
|---|---|---|---|
| Mount Pelee, St. Pierre, WI | Volcano<br>Ash, Heat, Toxic Gas | 23,000 | 1902 |
| Hurst Building Baltimore | Fire<br>140 Urban Acres | | 1904 |

| | | | |
|---|---|---|---|
| San Francisco | Earthquake, Fire 8.5 Richter | 1,000 | 1906 |
| Triangle Building New York City | Fire | 145 | 1911 |
| Eastland Chicago River | Capsized Excursion Boat | >2,000 | 1915 |
| Purity Distilling Boston | Molasses Explosion | 64 | 1919 |
| Tokyo-Yokahama | Earthquake, Fire | 250,000 | 1923 |
| St. Francis Dam Santa Clara, CA | Collapse -- Flood | 450 | 1928 |
| R 101 Airship London | Aircrash | 67 | 1930 |
| Moro Castle Havana | Fire at Sea | 134 | 1934 |
| Consolidated School New London, TX | Gas Explosion | 297 | 1937 |
| Hindenburgh Lakehurst, NJ | Explosion - Fire | 33 | 1937 |
| New England Coast | Hurrican-Winds-Flood | >600 | 1938 |
| Coconut Grove Club Boston | Fire | >492 | 1942 |
| Circus Hartford, CT | Tent Fire | 418 | 1944 |
| East Side Gas Co. Cleveland, OH | Explosion - Fire | 403 | 1944 |

| | | | |
|---|---|---|---|
| SS Grand Camp<br>Port, Texas City | Fertilizer Explosion | 752 | 1947 |
| Andes<br>Embado, Ecuador | Earthquake, Flood<br>7.5 Richter | >2,500 | 1949 |
| Missouri River<br>Kansas City, KS | Flood | | 1951 |
| Tangiwia Bridge<br>Mt. Ruapehu, NZ | Volcanic Eruption, Water<br>Mud Slide, Bridge Collapse<br>Train Crash | 151 | 1953 |
| Department Store<br>Bogota | Fire<br>Christmas Shopping | 132 | 1958 |
| New York City | Scheduled Airliner<br>Collision & Dwelling<br>Destruction | 223 | 1960 |
| Watts<br>Los Angeles, CA | Riot, Civil Disturbance<br>Fire | >730 | 1965 |
| Arno River<br>Florence, Italy | Flood | >100 | 1966 |
| Coastal Peru<br>Chimbote | Earthquake | >2,700 | 1970 |
| Yarra Bridge<br>Melbourne | Construction Failure | >35 | 1970 |
| San Fernando Valley<br>California | Earthquake<br>Hospital Collapse | >56 | 1971 |
| London | 2 Car Bombs, 1 parcel<br>Bomb simultaneously | 60 | 1973 |
| Le Drugstore<br>Paris | Terrorist<br>Hand Grenade | 14 | 1974 |

| | | | |
|---|---|---|---|
| Greece<br>Over Aegean | Bomb on Scheduled TWA Airliner | 88 | 1974 |
| Airliner<br>Suburban Paris | Aircraft Failure | >346 | 1974 |
| NYPRO Works<br>Flixborough, Eng. | Chemical Plant Explosion<br>Caprolactum (pre-Nylon) | >129 | 1974 |
| Kennedy Airport<br>New York City | Air Crash B-727<br>(Wind-shear?) | 112 | 1975 |
| Moorgate Tube Station<br>London | Subway Crash | 113 | 1975 |
| Charter Bus<br>Martinez, CA | Bus Crash | >25 | 1975 |
| Coastal Hopei<br>Peking, Tinstin<br>Tangsan | Earthquake<br>Flood | >100,000 | 1976 |
| Las Rodeos Airport<br>Tenerife | Ground-Ground Collision | 580 | 1977 |
| Beverly Hills Club<br>Southgate, KY | Holiday Fire | 290 | 1977 |
| Jonestown<br>Guyana | Mass Suicide and Homicide | >900 | 1978 |
| Three Mile Island<br>Harrisburg, PA | Nuclear Power Plant Accident | o? | 1979 |
| O'Hare Airport<br>Chicago | Aircraft Failure<br>Aircrash DC-10 | 272 | 1979 |
| Morvi<br>India | Monsoon, Dam Failure<br>Flood | >15,000 | 1979 |
| MGM Hotel<br>Las Vegas, Nev. | Fire | 384 | 1980 |

| | | | |
|---|---|---|---|
| Hilton Hotel<br>Las Vegas, Nev. | Fire | | 1980 |
| Mount St. Helens<br>Washington | Volcano<br>Ash, Toxic Gas | >23 | 1980 |
| Southern Italy<br>Ebboli | Earthquake, Buildings<br>Collapse | >10,900 | 1980 |
| National Airport<br>Washington, D.C. | Air Crash<br>(Icing) | 79 | 1982 |
| Beirut<br>Lebanon | Truck Bombing | 310 | 1983 |

The two sets of case reviews indicated to us that traditional, anecdotal disaster accounts had inadequate medical detail to introduce and apply the trends and advances described in Phase I of this study. A notable exception to this rule were the detailed studies carried out by the National Transportation Safety Board on air crashes. Even in these reports, emphasis was placed on the construction of the aircraft and insufficient information was available to allow us to devise new disaster rescue strategies which incorporated state of the art medical instrumentation, techniques and decision making.

## Detailed Case Reconstruction

Knowledge of the general conditions of the disaster, the expected configuration of injury, documents which provided only the cause of death within the limited terminology of the International Classification of Disease, and a general knowledge of the ad hoc rescue attempts involved failed to provide us with an understanding of the dynamics of the victims, injury process, the time intervals involved and the pathophysiological pathway to death. How should the rescue strategy and process be modified? Could it result in the salvage of additional lives? Could we devise changes in procedure whereby there was a reasonable probability of salvage and survival of a significant number of victims listed among the fatal body count?

From the cases studied in Part II we attempted to select combinations of disparate disasters sufficiently recent, separated geographically and for which we could obtain the essential access for detailed data. The Principal Investigator had previously dissected, analyzed and published the rescue milieu, decisional processes and the introduction of methodologies and technologies in conflict disasters (162, 164, 165). For this study disasters were selected from the natural and technological categories:

- San Fernando Valley Earthquake
- Mount St. Helens Volcanic Eruption
- Washington National Airport; Air Florida 90 Crash

<u>Disaster I</u>: <u>San Fernando Valley Earthquake</u>. The San Fernanado Valley -- Sylmar Valley -- is an idyllic area of Southern California which extends roughly parallel to the Pacific Coast. It is populated by moderate sized suburban towns, middle class bedroom communities, and is distinguished by its proximity to both the San Gabriel and San Andreas faults. The area is also the home of Dr. Charles Richter, on whose house a modest quake of 6.2 occurred at forty-seven seconds past 0600 on 9 February 1971 (144).

This became a mass casualty event because two hospitals, one operated by the Veterans Administration and one newly constructed as a private nonprofit institution, had been built in close proximity to the fault lines. Portions of both these buildings collapsed during the main portion of the quake. Simultaneously, almost all ground routes of access for rescue and evacuation, including rail and highway, were fractured and became unusable.

The hospital buildings, unlike the California residences, were built of structural steel and masonry and were, for the area, high rise buildings.

Patterns of Injury At the time of the quake both ambulatory and nonambulatory patients were generally in their beds and presented their prone bodies to falling and collapsing structural elements. The cause of the injury pattern was almost universally the result of patients being struck by or trapped within the collapsing buildings. A significant number of the hospital staff was trapped within the kitchens and other logistical areas on the lower floors.

The pattern of individual victim injury was equally consistent. It consisted predominantly of ventilatory failure secondary to mechanical chest injury accompanied by subsidiary multiple trauma due to blunt truncal injuries and crushing limb injuries. Had the patients, like the staff, been ambulatory, a much higher incidence of dominant head injury might have occurred.

RECORDED CAUSES OF DEATH IN SAN FERNANDO VALLEY EARTHQUAKE

| | | |
|---|---|---|
| Thoracic Cage Injury | | 24 |
| Mulitple Trauma | | 10 |
| Head Injury | | 9 |
| Hemorrhage | | 4 |
| Unidentifiable | | 4 |
| Massive Crush | | 3 |
| Cardiac | | 2 |
| | TOTAL | 56 |

Fifty-six people died in this calamity. Our analysis indicates that a larger number were trapped within the hospital buildings and required significant extrication by a larger manual force and by the use of heavy construction equipment. Indeed, the death rate would have been much higher except for the recent and fortuitous placement of a temporary Army Corps of Engineers construction site in the mountains to the east of the hospitals. The necessary heavy equipment required for extrication of the victims was brought in within the hour across country without requiring access to the highway system which was impassable. It is doubtful that this equipment could have been transported by air from distant sites soon enough for life salvage.

Of those who did die, our analysis indicated that forty-one (73%) were potentially salvageable in the interval between accident and death. Over half of the potential surviors were amenable to standard trauma life support by the placement of an endotracheal tube and positive pressure oxygen applied manually or by mechanical means.

## LESSONS LEARNED

- o Adequate, advance hazard assessment is essential in any area. This might have prevented the tragedy which occurred in California.

- o There is no need for multistory hospitals on known fault lines in suburban areas where adequate acreage is readily available.

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

- o It must be anticipated that access routes may be blocked my earthquakes. Therefore heavy extrication equipment such as tractors, winches and hydrualic jacks should be safely stored and the maintenance staff trained in its use.

- o Adequate hand ventilatory equipment should be stored, preferably in multiple sites.

- o The research lesson is in the demonstration of a need for the development of durable and more portable ventilatory equipment. (The advent of electromechancial 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 first move horizontally into a necklace of volcanos and then rises as high as 84 kilometers to reach the surface exploding ash and gases (carbon dixoide, ammonia, and sulfur based gases). In the case of Mount St. Helens, the explosion had the power of a 5000 megaton bomb and set up lava flows, mud flows, and a 5.0 earthquake (72).

By March 21, 1980 the eruption predicted for the twentieth century by Crandell and Mullineu in 1831 (53) had begun with the onset of preliminary quakes. On May 18 the lava bubble burst through the crater top and out the north face.

The event was, in a sense, a disaster preparation success. By denying thousands of recreationers access to the immediate area, government officials saved many lives. Nevertheless, 23 people died.

Examination of the physical surroundings in which they died and the physical evidence of the death scenes along with the medical autopsy records teaches a great deal about prevention of injury and the protection of rescue workers. Beyond the area of blast, lava flow, deadly thermal energy, and secondary floods from which people can be evacuated, volcanos hurl lethal, but potentially survivable ash and silica particles. Similar silica particles in small chronic inhalations cause silicosis. Wilcox (182) in his monumental 1959 study of Alaskan volcanic ash points out that commonly toxic gases are rapidly dissipated at high altitudes; however, the Laki Fissure eruption in Iceland in 1783 is reported to have produced a seven month fog of sulfur dioxide throughout much of Europe (95). Wilcox also predictively indicted silica ash as the lethal agent whose effect extends kilometers beyond the blast blowdown, avalanche and mud-flow zones.

Impacting tectonic plates, as opposed to separating plates produce a larger percentage of lethal silica (9), although Baxter et al relate extraordinary cases of toxic gas deaths from the Javan Dieng volcano. The twenty-five year degasing cycle of the low lying Masaya volcano in Nicaragua among others warns of the future possiblity of toxic gases from the low lying vents of Mount Shasta in Northern California (7).

Our reconstruction from the reports, videotapes, and photographs of the scene and the results of ash analysis support the findings of Eisele and his colleagues (63) that particulate silica ash was the chief lethal agent in the unevacuated victims at the periphery of Mount St. Helens damage zone, and the major barrier against escape and the use of rescue vehicles.

The reports of Baxter and his associates from the Center for Disease Control (7, 8, 9, 12, 13, 14, 22-44) and the Bulletins of the Federal Emergency Management Agency (71) suggest many of the lessons to be learned. Our reconstrcution concurs.

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

Only the lethal silica ash traveled far enough to produce a distinct pattern of energy 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. Small silica particles at various temperatures were inhaled and 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 source 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 inexpensive industrial masks which incorporate eye protection.

CAUSES OF DEATH IN THE MOUNT ST. HELENS ERUPTION

| | |
|---|---|
| Ventilatory Failure | 17 |
| Burns | 5 |
| Head Injury | 1 |

LESSONS LEARNED

- Hazard assessment and updated intelligence do provide the predictive bases for evacuation and perimeter policing in the case of volcanic eruption, which is a largely forseeable disaster.
- Hazard assessment should include seismic monitoring, emergency ash analysis stations, and emergency air monitoring stations.
- There is a distinct need for an education and training program for local physicians and other hospital personnel in the management of acute silica inhalation and ventilatory failure. There is a distinct need to alert local health authorities to prepare for mass trauma casualties.

- o Area residents, rescue, and clean up workers should be provided with the low cost, high efficiency goggles and masks. This equipment which is readily available should also be deployed in advance in appropriate areas.
- o Trauma centers should be evaluated and designated in advance.
- o 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 air traffic at Washington D.C.'s National airport probably transports as many, if not more, policy makers, global scholars, and other VIPs as any airport in the world. 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 borders National Airport and the city, was frozen and the transPotomac bridges between the heart of the city and its bedroom suburbs were crowded with early rush hour traffic at 4:01 PM. Within less than an hour the storm was responsible for multiple urban auto crashes and the crash of a scheduled airliner whose aerodynamics were significantly deformed by icing. To compound the problems, a local subway train also wrecked during this period.

On board the plane were seventy-four 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 relatively slowly struck the ice covered water at a twenty-five to thirty degree pitch, nose first. The cabin separated from the cockpit and fractured into three fragments (140).

The evidence presented to the investigatory National Transportation Safety board led to the conclusion that the probable causes of this accident were ... 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 ... the Captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings ... and the inherent pitchup charcteristics of the B-373 aircraft (140).

Of the seventy-nine passengers and crew aboard, five survived.

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

There are three criteria for survival in an airplane crash:

- o The deceleration forces must not exceed the known tolerable limits of the human. In this case there is evidence that the primary impact forces experienced by the passengers did not exceed those limits.
- o The restraint system (seat belt, seat structure, and seat anchorage) must remain intact; this criterion was not met.
- o The passenger occupied space must remain inviolate; this criterion 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. 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 all served to produce 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 four feet below the surface was 34 degrees F. which NASA data indicate would have caused unconsciousness in at least 50% 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 somewhere between 18 and 26 were salvageable by modern medical techniques and would have survived. This is 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 manageable conditions remediable in our Level I trauma centers.

## LESSONS LEARNED

- It is a myth that all large passenger aircraft crashes are totally and irretrievably fatal.
- Aircraft may crash at deceleration G's which permit survivability and should be designed to allow passenger escape.
- 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.
- Passenger instruction in the use of and the design of escape and floatation gear are grossly inadequate.
- 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 responsiblity of emergency medical services command.
- Medical personnel and hospital units should be appraised 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 AND RECOMMENDATIONS

In an effort to investigate and examine areas for improvement in disaster rescue, more than one hundred disasters were examined. Thirty-three were examined in order to develop a background and taxonomy. Forty-eight were investigated in greater detail in order to develop an appreciation of the level of documentation of the resuce and medical aspects available. Of these, three were selected and sufficient information gathered in order to attempt a reconstruction of the injuries and the pathophysiological pathway to death. It was evident that, with some exceptions, there was insufficient documentation generally available from anecdotal accounts to form a basis for detailed investigation. The circumstances of disaster place an emphasis on victim identification and legal cause of death. Only detailed autopsy material together with knowledge of the terrain and the circumstances provide a basis for methodological improvement.

In each of the reconstructed cases there were dominant patterns of injury which were amenable to prediction by this detailed reconstruction methodology and regional hazard assessment. In the earthquakes studied, 73% of the dead were considered potentially salvageable under significantly improved conditions of preparation and medical rescue. Seventy-four percent of the victims of a volcanic eruption presented a consistent pattern of injury which was potentially preventable had the pathophysiology been understood in advance and simple protective equipment been distributed as a preparatory effort or during rescue attempts. The reconstruction of the crash of a scheduled airliner indicated that 25% of those who died were eligible for successful rescue under predictable conditions had the rescue effort and equipment been optimized in accordance with the state of the art of assessment and prediction, equipment, and medical techniques.

While it cannot be said with any certainty whether these victims would have survived, the reconstructions indicate the need for a reassessment of the state of the art of disaster management.

In response to specific contractual requirements, the civilian disaster triage decision process was examined in the light of the case evidence and the existing literature. Triage is a term loosely defined and an unevenly applied process in the decisional strategy for the management of casualties. As currently used it is applied to the prioritization of candidates for rescue, the level of transportation of and the distribution of medical resources at various levels of the management process. The triage decision process should represent a balancing of human needs with available resources. Triage personnel should have advance knowledge of the details of injury patterns and the resources available.

The disaster literature describes the process as essentially unchanged since the post World War II era. The state of the art of the care of trauma victims including the decisional processes in circumstances other than disaster has, however, improved considerably. There is a trend toward the quantification of injuries as a component of the triage process. The advances in critical care medicine (reanimation) have been transferred to trauma rescue so that life support procedures are incorporated in the extrication and rescue process, thus salvaging the patient so that other advanced techniques can be applied in order to definitely repair damage within the intrahospital setting.

There is a movement to standardize and increase the capability of civilian hospital resources by the establishment of regional trauma centers.

The detailed studies have indicated that there are dominant patterns of injury for specific subtypes of disaster.

## RECOMMENDATIONS

1. That communities be encouraged to conduct regional hazard assessement and resource inventories in order to provide training and materials in preparation for the injury patterns of anticipatable disasters.

2. That, where appropriate, inexpensive protective equipment be distributed to threatened population groups andthat members of each household or each neighborhood be trained to respond to the event of warnings of an impending disaster.

3. That regional rescue be centered around regional trauma centers and the rescue process made the responsibility of those centers in conjunction with police, fire, utility and other responsible agencies.

4. That research be conducted in order to bring the state of the art of medical rescue in mass casualty situations up to the level of modern trauma care.

5. That regional triage teams be trained consistent with the results of regional hazard assessment, provided with uniforms, equipment and access to emergency transportation.

6. That standard disaster research, autopsy,and evidence examination protocols be developed analagous to those used for the study of highway accidents.

7. That a special team of forensic pathologists, traumatologists, emergency medical personnel, engineers and other forensic scientists be trained and made available for dispatch to

assist local authorities and to collect an adequate national file of disaster data.

8. That the development of a National Disaster Medical Institute be accelerated within the Federal Government. This Institute should have a two-fold objective:

a) to train Federal, State, county and non-governmental emergency service personnel in all aspects of disaster planning and management;

b) to expand current research efforts for developing techniques that would enchance the chances for survival of victims of a disaster or similar event.

## SUMMARY

The objective of this study is to determine whether improvements can be made in the disaster rescue process in order to increase the survival of victims who now die. In addition to a review of the available literature on the triage decision process the investigation reviewed over one hundred disasters and attempted to "reconstruct" several disparate disasters from autopsy reports and other evidence.

The report includes a description of the state of the art of civilian disaster triage and medical rescue. Disaster medical procedures are contrasted with the much more advanced state of the art of trauma care in general.

The essential findings of the study are that:

- o there is a multidecade gap between the state of the art of civilian disaster medical rescue including triage formulae and present levels of trauma care in the United States;
- o there is evidence that a significant percentage of victims who die in disasters could be saved by improved medical rescue techniques and disaster management strategy;
- o a set of recommendations to close this gap are derived and presented herein.

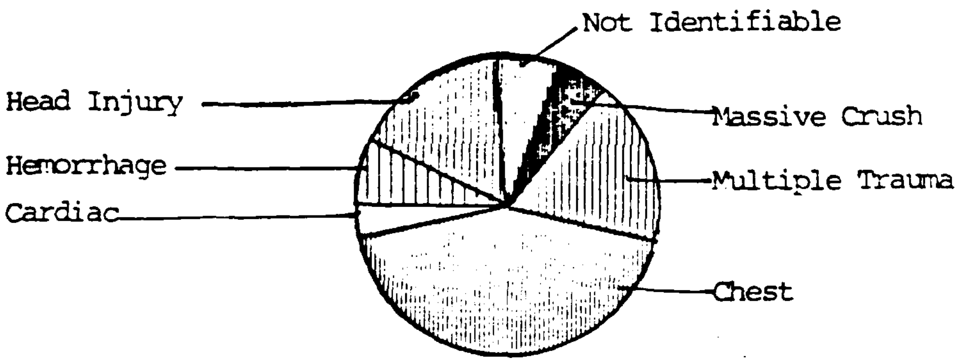
DATA

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

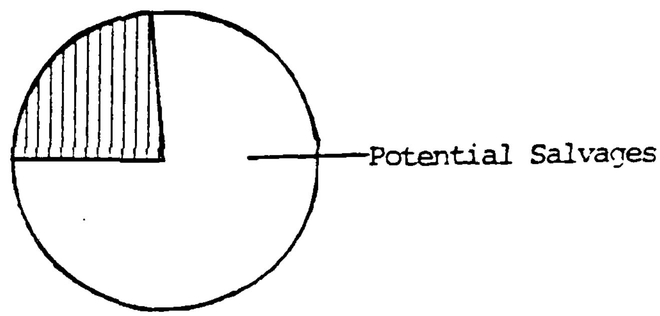
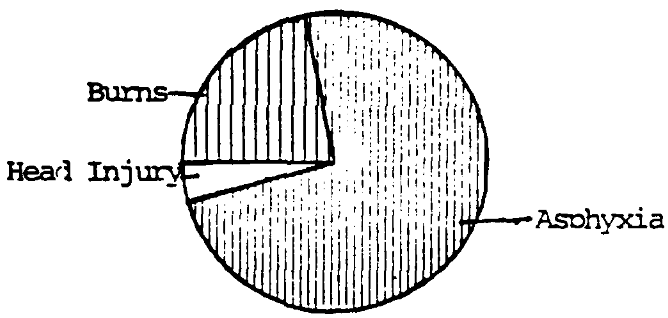


Table 2

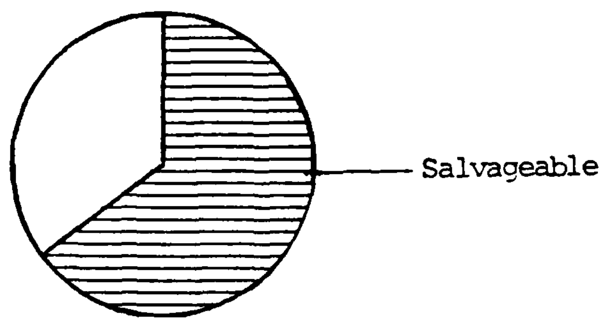
CAUSES OF DEATH MOUNT ST. HELENS ERUPTION

| | |
|---|---|
| Ventilatory Failure | 17 |
| Burns | 5 |
| Head Injury | 1 |

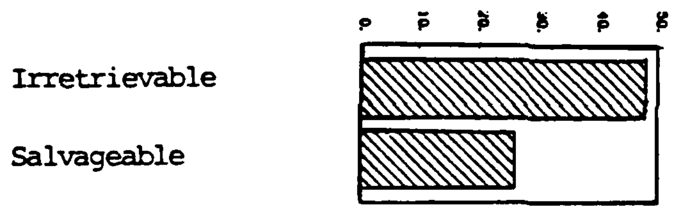
MOUNT ST. HELENS



MOUNT ST. HELENS



AIR FLORIDA CRASH



## DISASTER CASES

### GROUP I

| Natural | Technological | Conflict |
|---|---|---|
| Galveston Flood<br>1900 | Chicago Theater Fire<br>1903 500 casualties | Luisitania Sinking<br>1000 casualties |
| Sicily Earthquake<br>1908<br>100,000 casualties | SS General Slocum<br>1904<br>Steamboat Fire | SS Mont Blanc<br>Munition ship explosion<br>1000 casualties |
| Ohio Ind. Flood<br>1913<br>3000 casualties | Cherry, Ill. Mine Cave-in 1909<br>400 casualties | Ohio Prison Fire & Riot 1930<br>335 casualties |
| Tornado Illinois<br>1925<br>3600 casualties | Titanic Sinking<br>1912<br>1250 Casualties | Civil Disturbance in Brazil 1930 |
| Hurricane Carribean<br>1926<br>650 casualties | SS Empress of Ireland Sunk in Fog 1914<br>954 casualties | Striker-Police<br>New York City |
| Tornado St. Louis<br>1927<br>669 casualties | Salem, Mass. Fire<br>1914 | Mosely Police Riot<br>London 1961 |
| Southeast U.S. Hurricane<br>1928<br>400 casualties | ZR2 Airship Explosion<br>London<br>1921<br>33 casualties | Kennedy Assassination<br>1963<br>Dallas* |
| Naples Earthquake<br>1930<br>639 casualties | Oppau, Germany 1921<br>Industrial Explosion<br>3000 casualties | Airliner Machine-gunned, Zurich 1969<br>6 casualties |
| Baluchistan Earthquake 1935<br>20,000 casualties | St. Francis Dam Collapse<br>Los Angeles 1928<br>974 casualties | Marks & Spenser stores firebombed<br>London 1969 |

| | | |
|---|---|---|
| Florida Hurricane<br>1935<br>200 Casualties | Cleveland Clinic<br>Toxic Gas 1929<br>100 casualties | Airport bus grenade<br>Munich 1970<br>13 casualties |
| 12 State Flood<br>1936 | U.S. Airship Akron<br>1933<br>73 casualties | Mid-air bomb<br>Zurich 1970<br>47 casualties |

* The injury or death of a single individual may, under certain circumstances, threaten the fabric of a society (See Glossary definition of disaster).

GROUP II

| Disaster | Type | Casualties | |
|---|---|---|---|
| Mount Pelee, St. Pierre, WI | Volcano Ash, Heat, Toxic Gas | 23,000 | 1902 |
| Hurst Building Baltimore | Fire 140 Urban Acres | | 1904 |
| San Francisco | Earthquake, Fire 8.5 Richter | 1,000 | 1906 |
| Triangle Building New York City | Fire | 145 | 1911 |
| Eastland Chicago River | Capsized Excursion Boat | >2,000 | 1915 |
| Purity Distilling Boston | Molasses Explosion | 64 | 1919 |
| Tokyo-Yokahama | Earthquake, Fire | 250,000 | 1923 |
| St. Francis Dam Santa Clara, CA | Collapse -- Flood | 450 | 1928 |
| R 101 Airship London | Aircrash | 67 | 1930 |

| | | | |
|---|---|---|---|
| Moro Castle<br>Havana | Fire at Sea | 134 | 1934 |
| Consolidated School<br>New London, TX | Gas Explosion | 297 | 1937 |
| Hindenburgh<br>Lakehurst, NJ | Explosion - Fire | 33 | 1937 |
| New England Coast | Hurrican-Winds-Flood | >600 | 1938 |
| Coconut Grove Club<br>Boston | Fire | >492 | 1942 |
| Circus<br>Hartford, CT | Tent Fire | 418 | 1944 |
| East Side Gas Co.<br>Cleveland, OH | Explosion - Fire | 403 | 1944 |
| SS Grand Camp<br>Port, Texas City | Fertilizer Explosion | 752 | 1947 |
| Andes<br>Embado, Ecuador | Earthquake, Flood<br>7.5 Richter | >2,500 | 1949 |
| Missouri River<br>Kansas City, KS | Flood | | 1951 |
| Tangiwia Bridge<br>Mt. Ruapehu, NZ | Volcanic Eruption, Water<br>Mud Slide, Bridge Collapse<br>Train Crash | 151 | 1953 |
| Department Store<br>Bogota | Fire<br>Christmas Shopping | 132 | 1958 |
| New York City | Scheduled Airliner<br>Collision & Dwelling<br>Destruction | 223 | 1960 |
| Watts<br>Los Angeles, CA | Riot, Civil Disturbance<br>Fire | >730 | 1965 |

| | | | |
|---|---|---|---|
| Arno River<br>Florence, Italy | Flood | >100 | 1966 |
| Coastal Peru<br>Chimbote | Earthquake | >2,700 | 1970 |
| Yarra Bridge<br>Melbourne | Construction Failure | >35 | 1970 |
| San Fernando Valley<br>California | Earthquake<br>Hospital Collapse | >56 | 1971 |
| London | 2 Car Bombs, 1 parcel<br>Bomb simultaneously | 60 | 1973 |
| Le Drugstore<br>Paris | Terrorist<br>Hand Grenade | 14 | 1974 |
| Greece<br>Over Aegean | Bomb on Scheduled TWA<br>Airliner | 88 | 1974 |
| Airliner<br>Suburban Paris | Aircraft Failure | >346 | 1974 |
| NYPRO Works<br>Flixborough, Eng. | Chemical Plant Explosion<br>Caprolactum (pre-Nylon) | >129 | 1974 |
| Kennedy Airport<br>New York City | Air Crash B-727<br>(Wind-shear?) | 112 | 1975 |
| Moorgate Tube Station<br>London | Subway Crash | 113 | 1975 |
| Charter Bus<br>Martinez, CA | Bus Crash | >25 | 1975 |
| Coastal Hopei<br>Peking, Tinstin<br>Tangsan | Earthquake<br>Flood | >100,000 | 1976 |
| Las Rodeos Airport<br>Tenerife | Ground-Ground<br>Collision | 580 | 1977 |

| | | | |
|---|---|---|---|
| Beverly Hills Club<br>Southgate, KY | Holiday Fire | 290 | 1977 |
| Jonestown<br>Guyana | Mass Suicide and<br>Homicide | >900 | 1978 |
| Three Mile Island<br>Harrisburg, PA | Nuclear Power Plant<br>Accident | o? | 1979 |
| O'Hare Airport<br>Chicago | Aircraft Failure<br>Aircrash DC-10 | 272 | 1979 |
| Morvi<br>India | Monsoon, Dam Failure<br>Flood | >15,000 | 1979 |
| MGM Hotel<br>Las Vegas, Nev. | Fire | 384 | 1980 |
| Hilton Hotel<br>Las Vegas, Nev. | Fire | | 1980 |
| Mount St. Helens<br>Washington | Volcano<br>Ash, Toxic Gas | >23 | 1980 |
| Southern Italy<br>Ebboli | Earthquake, Buildings<br>Collapse | >10,900 | 1980 |
| National Airport<br>Washington, D.C. | Air Crash<br>(Icing) | 79 | 1982 |
| Beirut<br>Lebanon | Truck Bombing | 310 | 1983 |

DRAFT TRIAGE

PROTOCOLS

I Victims with minor injuries who are able to extricate themselves and leave the scene of the disaster unassisted.

II Nonambulatory victims who require some form of extrication and nonurgent transportation but no life support.

III Nonambulatory victims who require some form of extrication, no life support but urgent transportation to an appropriate hospital resource.

IV Victims who require life support during or after extrication and urgent transportation.

V Victims who require life support and urgent surgery at the site if immediate access to an appropriate hospital resource is not feasible.

VI Irretrievable or inextricable victims who require relief from pain and appropriate psychological support.

VII Inextricable victims who require no care and the deceased. These victims will require eventual extrication and identification and examination.

SAMPLE TRIAGE PROTOCOLS

I Slight injuries which can be managed by self help or by nurses and technicians

II Injuries which require medical care but which can be managed at least partially by paramedical personnel

III Injuries which require major surgical management either: (a) without delay; (b) with delay for resuscitation; or (c) with delay commensurate with further study and the needs of the patient

IV Injuries which are beyond repair

In this same category are simple systems designed to sort victims by transportation needs. One classic example:

I Ambulatory, no immediate care needed

II Ambulatory, delayed care acceptable

III Requiring immediate care on site

IV Urgently requiring hospital level care

V Deceased or unsalvageable

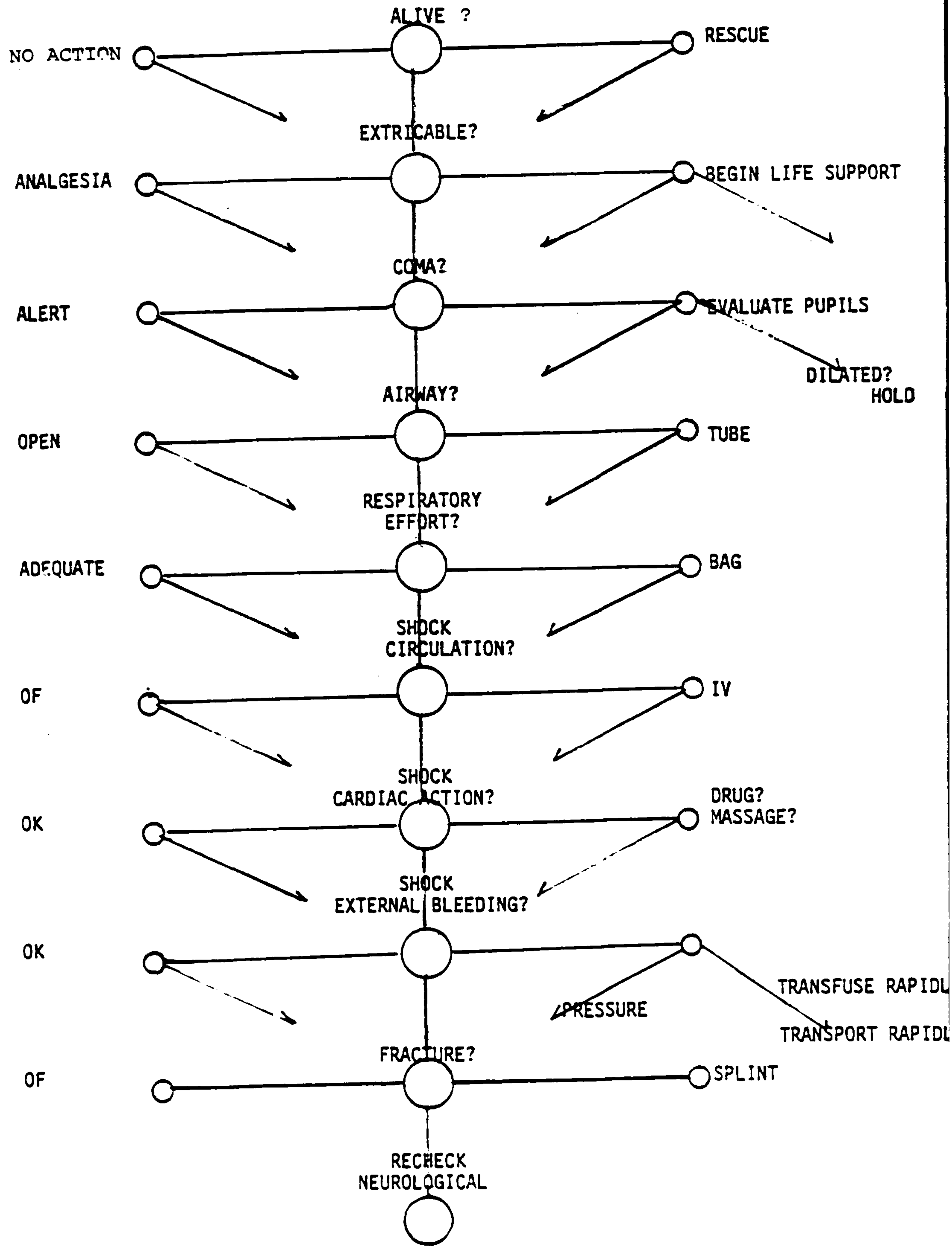
I Green Tag -- Casualties requiring minimal treatment as outpatients or requiring domiciliary care

II Red Tag -- Casualties requiring immediate treatement and whose chances of recovery are good after immediate definitive care

III Yellow Tag -- Casualties requiring treatment but who could tolerate delay, with chances of recovery considered good after definitive care

IV Blue Tag -- Casualties requiring expectant treatment with poor chances of recovery because of the magnitude of the injury and/or because an excessive committment of personnel and material would be required

TRIAGE DECISION ACTION TREE




TRIAGE DECISION ACTION TREE

# GLOSSARY

ADVANCED TRAUMA LIFE SUPPORT (ATLS): A short curriculum for practicing medical personnel designed to provide state of the art information and practice in state of the art techniques for the management of injury cases.

CRITICAL CARE (Intensive Care, Reanimation): Manpower and equipment intensive specialty of medicine which is designed to provide external support for failing or failed vital organ systems.

DISASTER: Any permutation of events which destroys property and threatens lives so as to overwhelm local resources and disrupt the fabric of society.

HAZARD ASSESSMENT: Determination of the potential disasters which threaten any community or region. Includes calculation of the probabilities of such events, the expected range of casualties, the likely patterns of injury, anticipated disruption of essential services, and time frame.

LIFE SUPPORT: The field techniques derived from critical care medicine and applied in order to "buy time" until definitive repair can be applied. Principally the maintenance of cardiovascular volume, the cardiac pump, and the respiratory apparatus resulting in the maintenance of cellular respiration and the protection of the immune systems.

NEAREST HOSPITAL RULE: The practice of transporting patients from the scene of a disaster to the geographically most proximate hospital without determination of the specific capabilities of that hospital at that moment.

PATTERNS OF INJURY: The configuration of local and systemic destruction to the body brought about by a specific event. Example - burns, fractures, foreign body penetration as a result of bomb blast.

RESCUE: The initial disaster response action directed toward victims of disaster. Includes extrication, essential medical care, and transportation to safety.

SITE: As used herein refers to the immediate location at which a disaster occurs and to the area where initial medical care is provided.

TRIAGE: The sorting out and classification of casualties of war or civilian disasters in order to determine priority of need, nature of need, medical resources required, and necessary transportation.

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