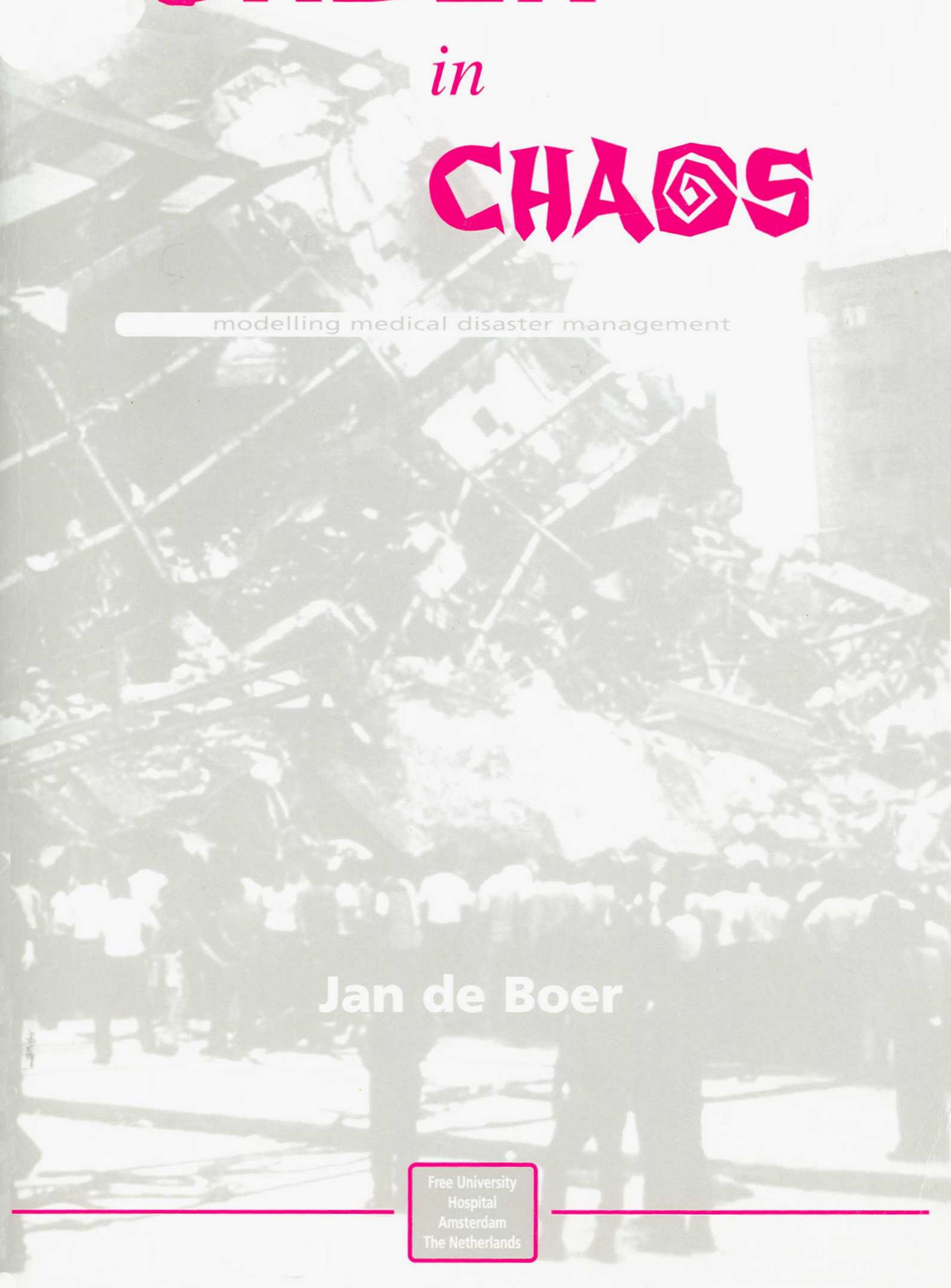
ORDER *in* CHAOS

modelling medical disaster management



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ORDER IN CHAOS

modelling medical disaster management

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DEDICATED TO THOSE MENTIONED IN THE LIST OF REFERENCES WHO MADE THIS BOOK POSSIBLE.

AN INTRODUCTION TO DISASTER MEDICINE*

* ADAPTED FROM AN ARTICLE IN THE
JOURNAL OF EMERGENCY MEDICINE (1995)

What is disaster medicine?

Disaster medicine is the combination of medical and medico-organisational management during disaster.

DISASTER MEDICINE

Medical

Mass casualty treatment:

- triage
- basic life support
- advanced life support
- surgery/traumatology
- anaesthesiology/resuscitation
- internal medicine/toxicology/ nuclear medicine
- forensic medicine
- psychology
- nutrition
- hygiene
- rehabilitation

Medico-organisational

- definition/classification/scoring
- epidemiology/prevention
- legislation
- command/coördination/ communication
- relief organisations
- relief material
- management:
  - at the site
  - transport and distribution
  - hospital procedures
  - evacuation
  - sanitation
  - nutrition

Information Education Training

Curriculum Education and Training in Disaster Medicine by International Society of Disaster Medicine

WHAT IS DISASTER MEDICINE?

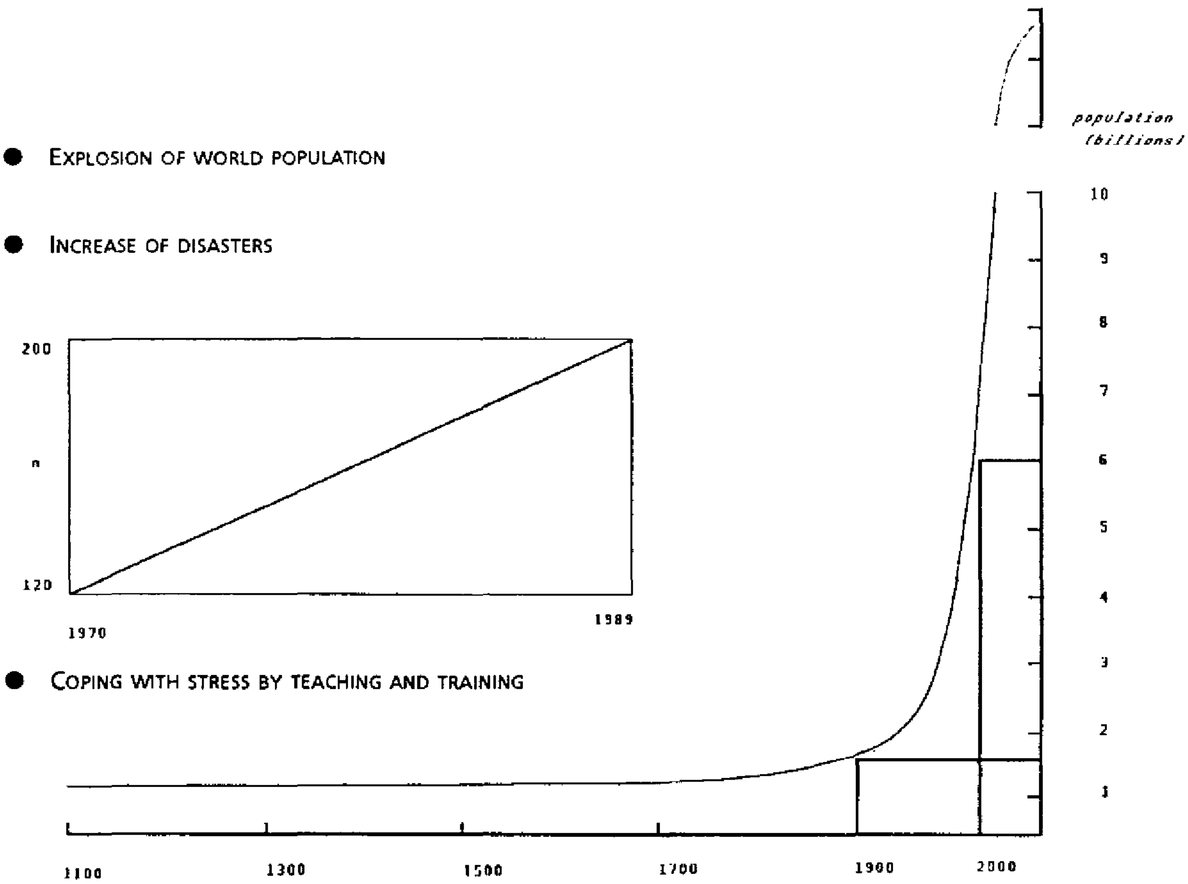
The treatment of large numbers of victims in chaotic circumstances creates problems with which the medical world is never faced in day-to-day practice. It is an illusion to believe that these problems can be tackled on the basis of improvisation. If suitable measures are taken, however, it is possible to achieve results which approach present-day standards of medical practice. The complex of medical and medico-organisational actions undertaken in the case of disasters is known as disaster medicine. This term covers the whole range of medical care and organisation from the scene of the disaster to the hospital bed.

Disaster medicine is based on two pillars: an old pillar military medicine and a new one emergency medicine. It is a young but rapidly growing branch on the old tree of medicine and has links with sociology, management and physical sciences. It has found its way into the curriculum of the medical student all over the world.

Since disasters imply dreadful consequences for mankind, attempts will be made to avoid them and should such measures fail, to restrict the consequences to a minimum. The latter requires a disaster organisation not only to deal with the disaster technically but especially to save human lives and to assure casualties of the best possible quality of life in the future. Therefore, disaster medicine is an important element in the entire combat against disaster.

Why disaster medicine?

- Explosion of world population
- Increase of disasters
- Coping with stress by teaching and training



WHY DISASTER MEDICINE?

The probability for doctors and nurses to be confronted with the effect of a disaster is increasing considerably.
This is not only the result of the explosion of world population, but also the urge of mankind to gain more prosperity is never satisfied. As a consequence of the latter the number of man-made disasters is rising significantly. There are also indications that naturally-occurring disasters are on the increase. As a result of both the total number of disasters has doubled in less than three decennia.
A third argument for the development of disaster medicine is the need for education and training in this field. This is not only of importance for medical rescue workers, but also the public in general is susceptible to stress and needs to be informed in order to increase its stress resistance. The last, but not least, reason is a medical one, because the treatment of casualties is limited by proper timing, which garanties low mortality, morbidity and disability rates.
Besides these general reasons, each country might have its specific arguments, like for The Netherlands, as a delta area, its ever lasting threat of the sea and rivers.

What is a disaster?

According to most dictionaries a disaster is defined as a calamity or great accident without mentioning any criterion.

From a medical point of view these criteria are:

1 Casualties
2 Discrepancy between number and treatment capacity

1980 An international working party postulated a definition for a disaster:
A destructive event that causes a discrepancy between the number of casualties and their treatment capacity.

1981 A classification and scoring system was formulated.

Definition, Classification and Assessment of Disasters

A disaster can be defined as a destructive event which claims so many victims that a discrepancy arises between their number and the treatment capacity. A similar event without victims which does not cause this discrepancy should be called an accident. In an attempt to classify and to assess disasters, a disaster severity scale (DSS) was developed. This is based on the effect on the surrounding community, on the cause of the disaster and the time it took to make its impact, on the size of the disaster area, the number of victims, the average severity of the injuries and the amount of time needed by the relief services to clear the area. Assessment of some disasters in this way bore a reasonable similarity with the factual events. Although this scale is useful for retrospective research, it is of little use at the time of the disaster for rapid, adequate and above all efficient relief work. That is why a "medical severity index" was introduced which made it possible to assess the medical size of a disaster immediately. Only practical experience can make it clear whether or not all types of disasters can be satisfactorily indexed in this way.

A literature search of disasters from the past 40 years has shown that the majority of articles comprises anecdotal descriptions only. This indicates the need for more uniformity and standardisation of description. With the methodology mentioned a minority of articles could be used to analyse disasters, leading to clusters of disastertypes with consistent scores.

Therefore this definition, classification and scoring system could serve as a tool, to evaluate disaster properly. For further reading see one of the next chapters.

Disasters classification according to origin

Man made			**Naturally-occuring**
Traffic			Earthquake
Explosion			Flood
Collapse			Hurricane
Fire			Volcanic eruption
Poison gas			Avalanche
Panic			Meteoric collision
Civil disturbance			Drought
Nuclear accident			↓
Local wars →	Fugitives	→	Famine
			↓
		→	Epidemic

EPIDEMIOLOGY

In this table an outline is given of natural and man-made disasters. Twelve out of seventeen types of disaster result in victims with injuries requiring surgery. This illustrates the great involvement of surgeons and anesthesiologists in disasters. The victims of other disasters are treated by internists, lung specialists, specialists in nuclear medicine and general practitioners.

Of the natural disasters, earthquakes and famines are the most frequent, followed by floods, tornadoes, volcanic eruptions and landslides. Earthquakes and volcanic eruptions are confined to tectonically unstable areas, floods to low-lying delta areas and tornadoes to areas affected by certain specific meteorological conditions.

Certain types of man-made disasters are linked to particular geographical areas, without this being explicable in terms of different degrees of industrialisation. For example, the number of road deaths in the United States, a highly industrialised country, is lower than in many European countries.

Over the last 25 years road and air traffic have more than doubled in most countries, the (petro) chemical and other industries have expanded considerably, and civil disturbances in the world seem to be on the increase. The chance that a disaster will take place is, therefore, much greater, unless organisational and technological measures to prevent them increase at the same rate. Whether attention has been paid to the latter is, however, questionable, given the large number of disasters and victims during this period.

The risk of a disaster occurring can be limited by technological and organisational means. In the past years many human lives have been saved by evacuation of a number of Chinese cities on the basis of correct short-term seismological predictions of an earthquake. In California extensive research is being carried out into long-term earthquake prediction. Other examples of prevention are the tornado warnings in the prairie provinces of Canada, the hurricane warnings in the South East of the USA and dyke watches in the Netherlands during gales.

With a proper definition, classification and scoring system disasters can be analyzed for a variety of features. This is dealt with in one of the next chapters.

Local and regional rescue organisations

Local	police fire brigade ambulance services hospitals doctors and nurses, independent or as members of rescue teams industrial organisations, e.g. railways, air and seaport authorities.
Regional	Ministry of Health (regional office) Ministry of Food (regional office) social services technical services doctors and nurses, independent or as members of rescue teams

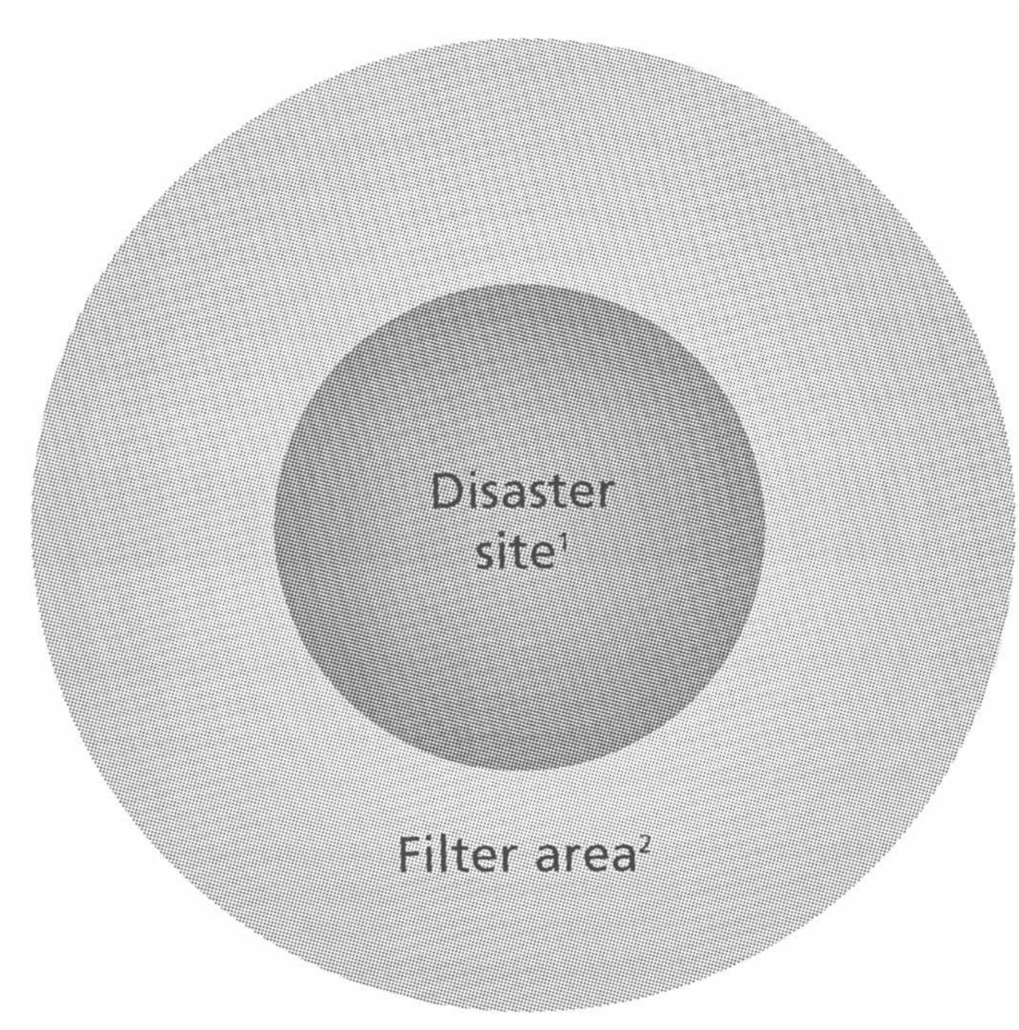
National and international rescue organisations

National	Ministry of Health Ministry of Internal Affairs Red Cross Armed Forces the Media (radio, television, post- office, telephone).
International	Hopital sans frontiére Médecins sans frontiére Register of Engineers for Disaster Relief Caritas Internationale Action d'urgence internationale Oxfam World Vision International Save the Children Fund Element Medical d'intervention rapide (France) Swedish Standby Force Corps Suisse pour l'aide en cas de catastrophe a l'étranger Disaster Area Survey Teams (USA) League of Red Cross Societies United Nations Disaster Relief Organisation World Health Organisation

Relief Services

Relief during disasters is organised at local, regional and national level. At a higher level there are international services. In general the services active at a local level are the police, the fire brigade, the health services, hospitals, and the competent authorities of air and sea ports, rail services and major industries.
The same services operate at regional level, while at national level the coordinating organisations of the Red Cross, the National Police Force, Civil Defence, the Ministry of Health, the Armed Forces and the mass media all play a role.
The purpose of the Civil Defence organisation is to conduct activities in (pre)wartime, but it may also be called upon in major disasters during peacetime. There are also international relief organisations such as the International Civil Defence Organisation, the United Nations Disaster Relief Organisation, the International Committee of the Red Cross, the World Health Organisation and even Interpol. International organisations can only offer a form of assistance in chronic situations. Immediate assistance is chiefly the responsibility for local and regional relief services.
One example of a specific disaster organisation is the Red Cross, which offers its services at local, regional, national and international levels. This organisation consists of thousands of enthousiastic helpers with first-aid training, but without any clinical experience, unfortunately perhaps at a time when modern traumatology is developing as a seperate specialism.

Professional medical relief located as close as possible to the the injured creates the best chance of survival. Non-expert treatment at the scene of the disaster, followed by an inevitably traumatic journey to hospital, adversely affects the prognosis for the injured person. It is therefore better to bring professional assistance from the hospital to the injured rather then first taking the injured to the hospital. This is why so-called crash teams are already operating in a number of countries and are in the process of being set up in others. These teams - for complicated and specific accidents and disasters usually consist of one or more specialists and nurses and their purpose is to provide advanced medical assistance in the case of complicated accidents.
The number of victims per unit of time that can be given treatment which accords with present medical standards at the scene of a disaster is known as the medical rescue capacity (MRC). This depends largely on the professionalism of the relief workers and not on the number of those with only first-aid training, who have been the ones most favoured usually by the authorities in many countries for the provision of medical assistance at disaster scenes.



1] DISASTER SYNDROME

2] COUNTER DISASTER SYNDROME

→ POST-TRAUMATIC STRESS DISORDER

Human Behaviour during Disasters

Human behaviour during disasters has been researched extensively. As a broad generalisation it can be said that most victims at the scene of a disaster suffer from "disaster syndrome", which is characterised by apathy, passivity or pointless activity. People hurry to the scene from the nearby area, after which a period of hyperactivity with little efficiency follows. This is called the "counter disaster syndrome". Work is done on developing a psychological approach to panic control and to the problem of unfortunate rumours being spread after the occurrence of a disaster. Certain patterns of behaviour can also be traced during evacuations. Post-traumatic stress disorders (PTSD) may develop among victims and relief workers as a (late) post-disaster effect .

Classification of victims according to the severity of the injuries sustained.

TRIAGE

Triage 1
ABC unstable victims due to obstruction of airway (A) or disturbance of breathing (B) or circulation (C).
Immediate life support. Urgent hospital admission.

Triage 2
ABC stable victims to be treated within 4-6 hours, otherwise they will become unstable.
First-aid measures. Hospital admission.

Triage 3
ABC stable victims with minor injuries not threatened by instability.
Can be treated by general practitioners.

TRIAGE: THE CLASSIFICATION OF THE INJURED

Disasters are characterized by shortage of (professional) personnel, material and thus time. In order to treat the maximum number of victims in the best way in the shortest possible time, classification of victims, according to the seriousness of the injuries sustained, is necessary. This classification, also known as triage, must be to the benefit of the patient and must also fit-in with the organisation of relief. Triage is based on the clinical impression of the existing and expected condition of the injured person, in other words on the "clinical appearance". It is known that triage of patients with injuries requiring surgery is best carried out by the most senior and therefore most experienced surgeon, and even with such expertise the task remains a difficult one. Various systems of triage have been developed, some of which have been in use for several decades. The Red Cross, for instance, uses a different system than the Civil Defence and this was different again from that used by the Armed Forces, but they are all primarily based on a classification according to the particular organic system that has sustained injury. Triage in hospital, however, must be created primarily to the medical organisation. Generally, three or four classifications are used in all forms of triage, where the triage 1 group normally represents the most seriously wounded and the triage 3 group those with minor injuries. To overcome the use of various triage systems in the chain of medical care, one uniform triage methodology and one uniform medical record system should be adopted.

Because hidden injuries are not immediately apparent, only being discovered after a period of time somewhere in the chain of medical care, re-classification may be necessary at that point. It is, therefore, essential to repeat the triage regularly along this chain so that these hidden injuries can be discovered in time and the overall health state can be reevaluated.
In one of the next chapters this topic is dealt with more extensively.

By rescue workers
with or without stretchers out of the impact area.

By other means
ambulance, car, heli, plane, train, boat.

VICTIM DISTRIBUTION PLAN
(medical transport capacity)

EVACUATION

Phases	Warning Departure Accomodation Return

The Transport and Distribution of Victims

The transport of the injured to hospital is usually carried out by local and regional ambulance services, coordinated by a Central Ambulance Transport Station. During disasters these may be backed up by ambulances belonging to the Red Cross and/or other relief organisations.
It is advisable for a number of ambulances to be stationed at the scene of the disaster to serve as first aid posts and as command and communications units. Moreover, each Central Ambulance Transport Station should have access to a plan for distributing the injured in the case of disasters, in which account is taken of the hospital treatment capacity of the surrounding hospitals (see below). The hospital nearest to the disaster area will have to be given a smaller share as it will be overrun by victims who are still able to walk. It should be noted that transport constitutes an additional trauma, especially for those who are seriously ill or badly injured. The number of patients that can be transported per unit of time according to current standards, represents the medical transport capacity (MTC).

Evacuation

The evacuation of survivors and those in danger is part of a general disaster plan. Evacuation can be divided into four phases: warning, departure, accomodation and return. The authorities are to a large extent responsible for the necessary organisation. The medical measures centre on preventive hygiene in places where many are crowded together, such as camps and barracks.

Phases: alarm
preparation
execution
evaluation

(Hospital treatment capacity)

USE: KISS PRINCIPLE*

* Keep It Simple Stupid

Hospital Disaster Procedures

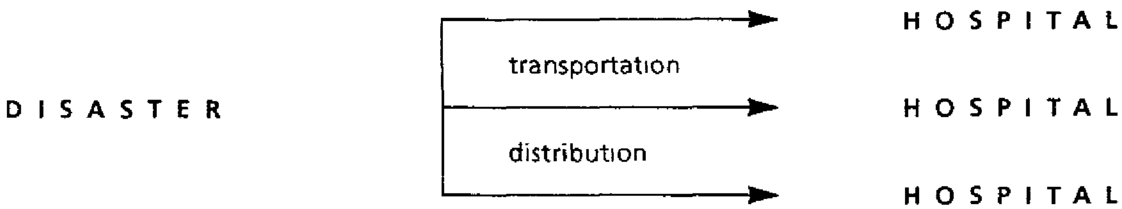
A hospital is a complex organisation in which routine procedures play a dominant role. If the number of patients exceeds capacity, which is different for each individual hospital, chaos can result unless the hospital can quickly switch to a disaster procedure. Such a procedure enable many patients to be admitted and treated in a short space of time.

This can only be done by postponing relatively minor matters and by simplifying and standardising treatment (see below).

The number of patients per unit of time that can be admitted and treated according to present medical standards is not direcctly dependent on the number of beds - up till recently the only criterion - but on the hospital treatment capacity (HTC). For patients with injuries needing surgery this capacity depends largely on the number of surgeons, anesthesiologists and scrub nurses available; for victims of (gas-)poisoning and epidemics it is largely dependent on the number of internists, toxicologists and lung specialists.

The disaster procedure in a hospital consists firstly of the different key personnel being alerted according to the "snowball" principle, each being responsible for alerting the next; then preparatory measures need to be taken, such as clearing areas for incoming patients, discharging patients, putting out instuments, drips, etc. as well as organising the traffic both in and around the hospital grounds. For further reading see one of the next chapters.

Chain of Medical Care



Medical rescue capacity (MRC)	Medical transport capacity (MTC)	Hospital treatment capacity (HTC)
Methods	Distribution plan	Disaster procedure
Personnel	Personnel	Personnel
Supplies	Ambulances	Supplies
Terrain and weather	Terrain and weather	Accomodation

The Chain of Medical Care

The medical organisation for disasters can be divided into three more or less closed organisational systems:

- the medical organisation at the site;
- the transportation and distribution of victims to and among neighbouring hospitals;
- the disasterprocedures for hospitals.

Along this chain of medical care, from the scene of disaster to the hospitalbed, the victim is medically handled and treated.
Each of the three systems has its capacity as mentioned earlier, the MRC, the MTC and the HTC, which are determined by personnel, material and methods.
To avoid stagnation in this chain synchronization of these capacities is imperative, which implies that they should be equal to one another. One could have a situation with a large medical resue capacity (MRC) at the disaster site and a small medical transport capacity (MTC), due to lack of ambulances, then the small MTC is determining the proper functioning of the chain. Thus the lowest capacity determines the capacity of the whole chain.
For calculations of the capacities the reader is referred to (one of) the next chapters.

Medical Procedures

UNIFORM TRIAGE

SIMPLIFICATION → OF PROCEDURES

STANDARDIZATION

---

priority for life- and limbsaving measures, postponement of less important procedures and uniform procedures for

drips,
antibiotics,
anticoagulants,
etc.

Surgery and Anaesthesia during Disasters

The effect of proper treatment for the right victims at the right moment is imperative. The triage 1 victims should be stabilized within the golden hour, while the triage 2 victims should receive adequate first-aid measures within 4-6 hours. The mass treatment of victims necessitates the implementation of certain principles. First of all, a uniform triage system must be used that is clear to all those involved in the chain of medical care. Secondly, diagnostic and therapeutic measures not directly aimed at the saving of lives, such as the taking of x-rays and the closing of wounds, have to be postponed or simplified. Thirdly, a standardisation of treatment is necessary, for example with regard to drips, bloodtransfusion and antibiotics. If every doctor and nurse working in the chain of medical care knows which triage and modes of simplication and standardization are being adhered to, this cuts down on the amount of information to be passed on and reduces the risk of unnecessary repetition. This approach worked excellently during the Falkland war.

For anaesthesia and analgesia the same principles apply. Analgesia depends largely on the circumstances: whether the patient is at the scene of the disaster, is being transported in an ambulance or has just arrived at hospital. Analgesia at the scene of the disaster is contra-indicated for injuries to head, chest or abdomen, only being considered for persons with injuries to their limbs. Oral, subcutaneous or intramuscular administration leads to longer absorption times when the patient is in shock, so intravenous administration is preferred. The transport of the injured over a short distance requires shorter-acting pain-killer to be given, whereas transport over a greater distance necessitates those with a longer action. It goes without saying that the injured parts of the body must be immobilised, wounds given a sterile cover and that an appropriate psychological approach to the victims should be adopted.

= multidisciplinary approach

---

matching

post-mortem ~ **ante-mortem**

of findings

---

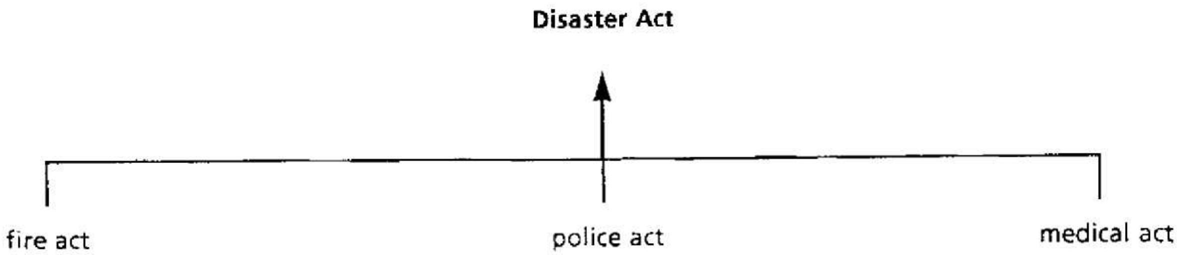
important for the bereaved:

- emotional
- judicial
- insurance

Identification of Victims

It is necessary to differentiate between disasters with "known names of dead" (e.g. an aeroplane crash) and those with "unknown names" (e.g. a fire in a department store). In the latter case identification is greatly impeded, but can be simplified by calling upon various medical disciplines. By taking a multi-disciplinary approach a high degree of reliability can be achieved. This is important for the bereaved, not only from an emotional point of view, but also for judicial and insurance purposes.

Identification of the dead is based on the matching of post mortem and ante mortem findings. The techniques utilized have reached a high rate of identificationperformance.



National, regional and municipal disaster plans should be centered around the chain of medical care and covered by a disaster act.

CONCLUSION

All the organisations, involved in disasters have to work together on disaster preparedness plans, which fit into the municipal, regional and national disaster plans and which are enforced in specific legislation governing disasters. In mass casualty situations the organisation dealing with the daily routine accidents should respond quickly, efficiently, and adequately by either expanding its own activities or call in specific disaster organisations like the Red Cross, Civil Defence or the Armed Forces. In this respect legislation should be enforced by a disaster law which should be in some way connected to the fire act, the police act and the medical act.

Triage methodologies for mechanical and chemical lesions should be developed, as well as treatment protocols for crash- and/or trauma-teams, for ambulance-personnel and for medical personnel in the emergency department of hospitals. These protocols should be based on simplification and standardization of procedures.

In the chain of medical care attackplans for the disaster site, victim distribution plans for ambulances and hospital procedures should be adopted in order to increase the efficacy of this chain. Only then can mass treatment take place that is adequate and efficient, and that meets present-day medical standards.

THE GENESIS OF DISASTER

ACTORS are based on:

and gates	A and B → C
&	
or gates	A or B → C

All kinds of combinations are possible:

A
and → C
B

A
or → C
B

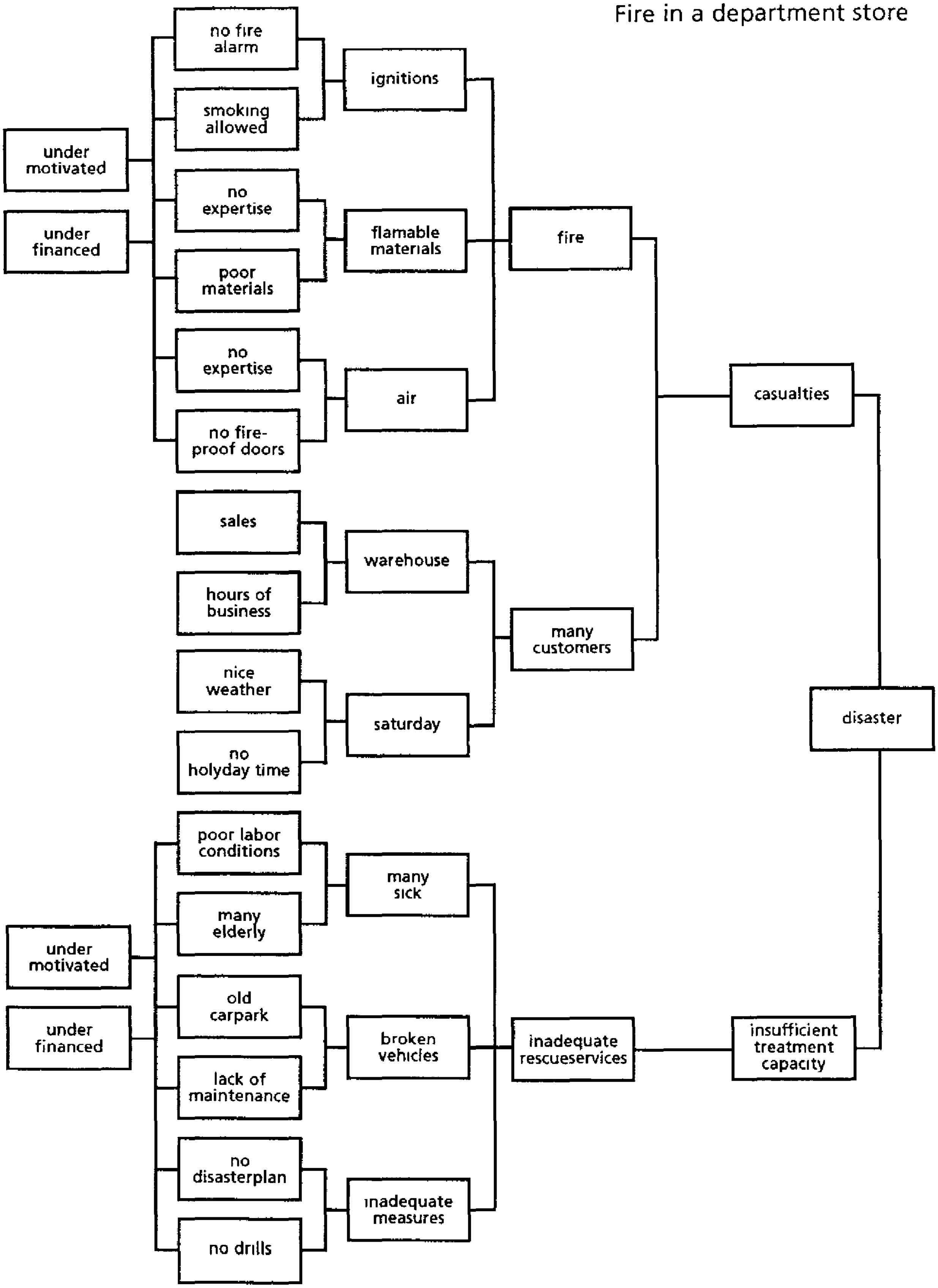
A
and
B
or → D
C

A
or
B
and → D
C

Man has always been intrigued by disasters. For many centuries disasters were considered as dooms of God. Up till the industrial phase only naturally occurring disasters were the menace of mankind. Increasing technology based on more and more scientific discoveries created a transition from an agricultural phase to an industrial one in the history of man. The latter not only introduced the ability to gain more prosperity, but also to gain more destructive power. As a complication of both, man-made disasters were the consequence. Together with the explosion of world population this has led to mass casualty situations, varying from traffic accidents to world wars.
More than 200 million people were killed in the 20th century, a cruel age without an equal in the history of mankind.

Anyway, man-made or cultural disasters are open for analysis. Many, so called actors originating from the past could lead to this kind of disasters. Since the ferry "Harald of Free Enterprise" usually left the port of Zeebrugge with open cargodoors to rid the cardecks of exhaust fumes, this in itself was not the final cause of its capsizal. However, should these doors have been closed, this disaster would not have happened. Many actors from the past have played a role in this dramatic occurrence. All actors leading to a disaster could be traced back into the past which is probably only true for man-made disasters and not for naturally-occurring ones. These actors can act together or alone.

Fire in a department store



Let us consider a fire in a department store, which is shown in the graph. This graph should be read from the right to left! The combination of a fire (= destructive event) and many people has led to a sudden discrepancy between number of victims and their treatment capacity. Fire is a combination of heat, air and flamable material. Because of bargain sales and the right time of the day and week, the department store was crowded with people. On the other hand among the rescue personnel many were sick, which in itself was caused by bad labour conditons and relatively more elderly. Quite a number of cars of the ambulance services were out of order, because of, among other things, insufficient maintenance. Fire could have spread easily, because of lack of fire and smoke sensors, while smoking was not prohibited. Air could easily reach the fire, because the fire proof doors were malfunctioning. The common denominators for the fire and the inadequate mobilisation of medical rescue personnel were insufficient financial means and lack of motivation, and probably both are linked to one another.

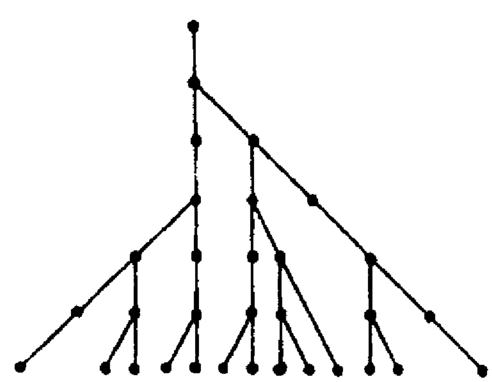
However with the birth of a new science, the mathematics of chaos, another new frontier for disaster medicine may be opened. This new science offers a way of seeing order and pattern where formerly only the random, the erratic, the unpredictable- in short the chaotic- had been observed. Research into this direction is initiated.

AN ALARM PROCEDURE*

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF EMERGENCY MEDICINE (1985)

Growth of a rabbit colony

Months	Adult Pairs	Young Pairs	Total
1	1	1	2
2	1	2	3
3	2	3	5
4	3	5	8
5	5	8	13
6	8	13	21
7	13	21	34
8	21	34	55
9	34	55	89
10	55	89	144



n	an	Sn
1	1	1
2	1	2
3	2	4
4	3	7
5	5	12
6	8	20
7	13	33

If each person calls two other people (assuming that each call takes one minute), then for seven minutes the following scheme can be obtained:
a_n, calls per minutes (n); S_n, total numbers of calls.

Disaster procedures are initiated by an alarm scheme. This scheme alerts all the personnel who are involved directly or indirectly. The wide variety of schemes in existence are usually based on the features of locally prevailing situations. An alarm is normally raised by one person who calls various other people. These people in turn will call other people, and so on, according to prearranged plans. Certain mathematical principles can be applied to calculate the number of people who can be reached within a fixed period of time; or to calculate the time needed to alert a fixed number of people. The basics for these mathematical principles were mastered already bij Fibonacci in mediaeval times.
In 1202 Fibonacci raised and solved the following problem: Rabbits breed rapidly. It is assumed that a pair of adult rabbits produces a pair of young rabbits every month and that newborn rabbits become adults in two months and produce, at this time, another pair of rabbits. Starting with an adult pair, how big will a rabbit colony be after the first, second, third, etc. month?
During the first month a pair is born so that there are two couples present. During the second month the original pair has produced another pair. One month later both the original pair and the first born pair has produced new pairs so that two adults and three young pairs are present, etc.
Let a_n denote the number of adult pairs at the end of the n-th month. Thus we get the following sequence:
$a_1 = 1, a_2 = 1, a_3 = 2, a_4 = 3, a_5 = 5, a_6 = 8, ...$

This is the famous Fibonacci sequence. It has the following remarkable property:
$2 = 1 + 1$ or $a_3 = a_1 + a_2$,
$3 = 1 + 2$ or $a_4 = a_2 + a_3$,
$5 = 2 + 3$ or $a_5 = a_3 + a_4$, etc.

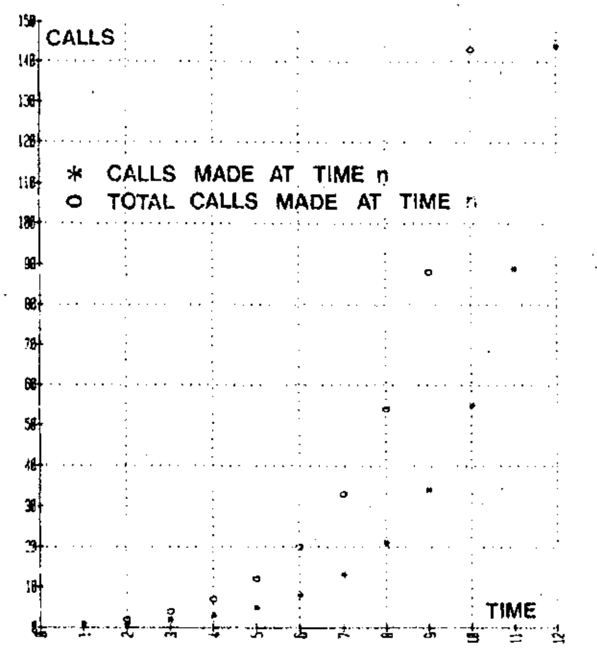
This sequence can also be applied to a certain alarm scheme. Providing that each person has to call two other people, the following scheme can be obtained, which in fact in a Fibonacci sequence. The number of people who can be called in each minute (assuming that each phone call takes one minute) is given by:

$$a_n = \frac{1}{\sqrt{5}} \bullet \left[\frac{1+\sqrt{5}}{2}\right]^n - \frac{1}{\sqrt{5}} \bullet \left[\frac{1-\sqrt{5}}{2}\right]^n$$

where n equals minutes.

Calls per minute and total numbers of calls after n minutes

Minutes (n)	Calls per minute (a_n)	Total number of calls (S_n)
1	1	1
2	1	2
3	2	4
4	3	7
5	5	12
6	8	20
7	13	33
8	21	54
9	34	88
10	55	143
11	89	232
12	144	376
13	233	609
14	377	986
15	610	1596
16	987	2583
17	1597	4180
18	2584	6764
19	4181	10945



Time versus calls for the first 12 minutes

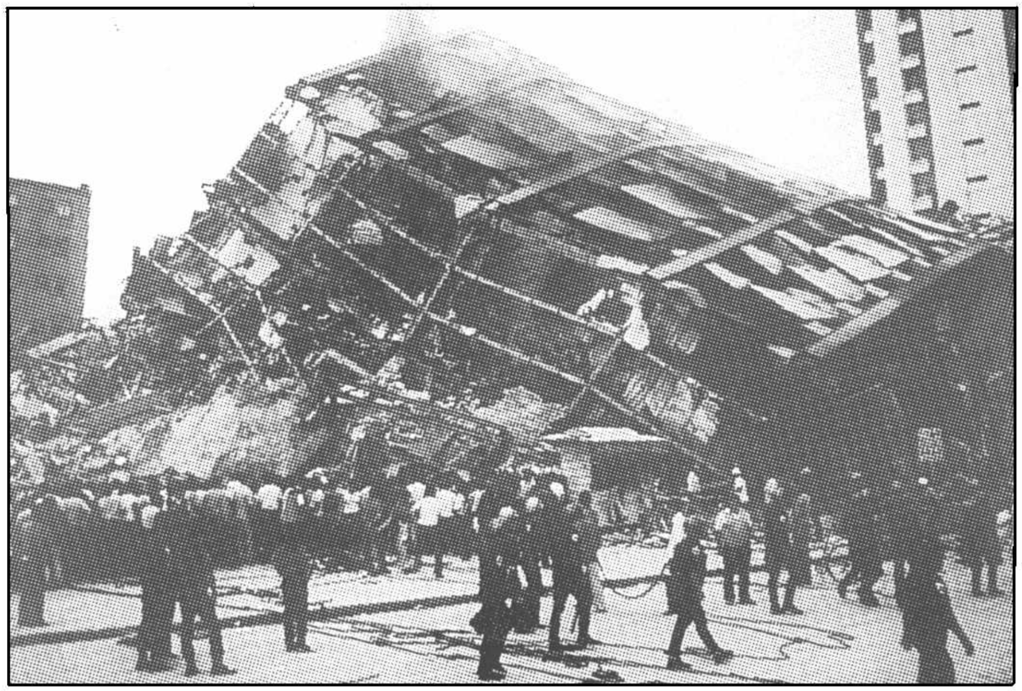
This equation looks rather complicated; however, with the pocket calculator it is easily calculated. For example, in the sixth minute (n=6) eight people are called; the total number of people called at that moment is, of course, the sum of the people called until that time and is given by:

$$S_n = a_{n+2} - 1$$

This implies that a table and a graph can be obtained of the total number of people alerted, the time required, and the calls per minute.
The advantage of this method is obvious, particularly if a large number of people have to be alerted; from a simple graph or table either the time or number of people required can be read. A formidable amount of people can be reached in a few minutes-in less than 20 minutes more than 10,000 people! Because each disaster procedure usually has its own alarm scheme some standardization of alarm procedures might be another advantage.
One disadvantage in the employment of this scheme, in which each individual calls two others, is that it may well be necessary, depending on the prevailing circumstances, to call one, or three, or even more. The second disadvantage is shown should any one person not answer the phone. In this case the caller should alert the two succeeding people of the missing person, which, of course, means that the graph or table no longer provides accurate figures.

DEFINITION, CLASSIFICATION AND SCORING OF DISASTERS*

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF EMERGENCY MEDICINE (1990)



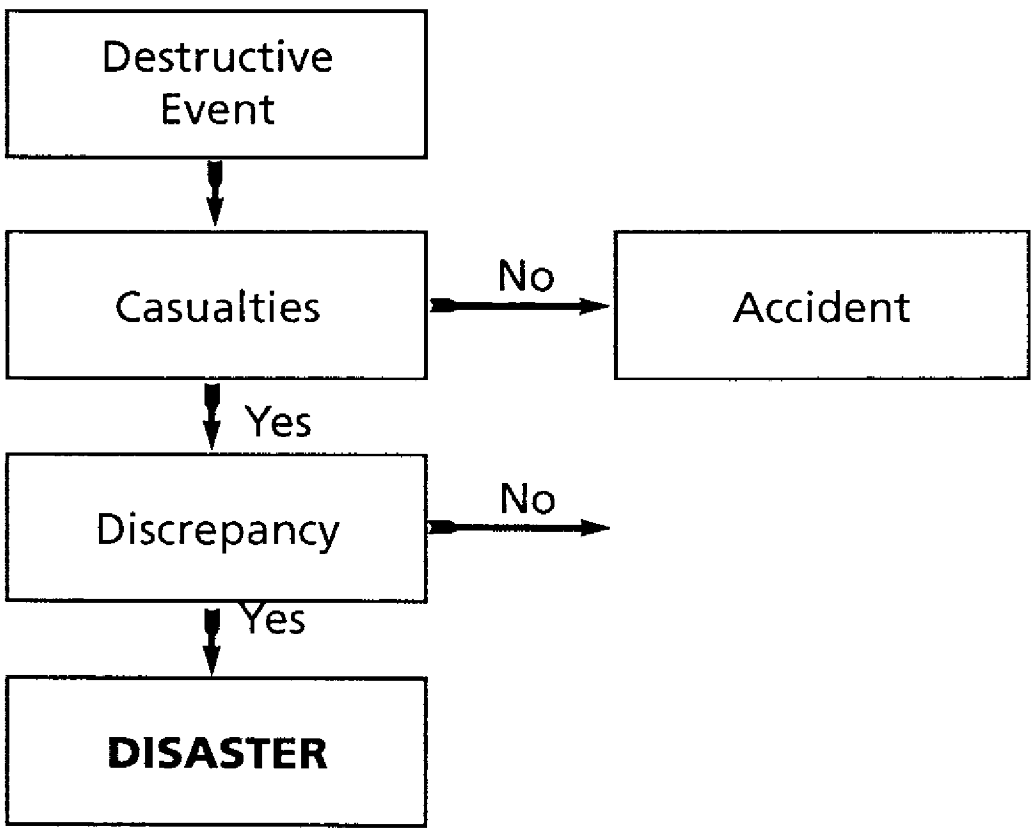
Man's experience down through the ages had frequently been attended by disasters of one kind or another. Our ancestors were tested by naturally-occurring disasters, whereas their modern descendants are also exposed to manmade hazards. In addition to loss of life and permanent disability of the victims, disasters produce considerable material damage.

It is difficult to evolve a meaningful definition of the word disaster. Most dictionaries identify this as a calamity or major accident and while this is correct, such a definition fails to reveal why a calamity or major accident should be a disaster. The word is applicable to everything from an event like an earthquake to occasions when two ladies turn up for a party wearing the same dress. From a medical point of view it is, therefore, of utmost importance to construct a simple definition for a disaster and, at the same time, to outline the criteria for its classification. Once such criteria have been determined, a scale can be evolved from which the gravity of the disaster can be assessed, which also allows the scientific comparison of various events.

Definition, classification, and measurement will create a foundation for that part of medicine called disaster medicine.

The first proposals for such a classification have come from William Rutherford. Later, an international working-party with representatives drawn from various countries and organizations continued his efforts and developed a meaningful definition. Simultaneously, a disaster severity scale was constructed. This chapter reviews these efforts and describes the methodology used.

A disaster can be defined as a destructive event that claims so many victims that a discrepancy arises between their number and the treatment capacity. A similar event without victims that does not cause this discrepancy would be called an accident.



Definitional algorithm following a destructive event

METHODOLOGY

Destruction of his hay shed by fire is a destructive event for the farmer, but not so for the neighbouring population. A serious traffic accident involving a bus with schoolchildren usually results in material damage with casualties and can be considered as a major accident for a town or village but hardly so for the region or province. These events can generally be dealt with adequately by the resources available locally (police, fire brigade, ambulance services, and hospitals). However, should the demands outstrip the potential of the resources, further aid can be obtained from neighbouring municipalities, and in this way the destructive event with casualties may acquire regional or even national proportion. This could be the case with floods or earthquakes. On the other hand, it is also conceivable that a country may be confronted with widespread destruction involving no threat to individuals or life.

From a medical point of view, a distinction should be made between destructive events with or without casualties and with or without extra mobilization of medical resources. A destructive event without casualties, but with extra mobilization of other than medical resources should be regarded as a calamity. A destructive event with casualties and without extra mobilization of medical resources should be considered as an accident, and with extra mobilization of medical resources as a disaster. Consequently, a disaster was defined as a destructive event that causes so many casualties that extra mobilization of medical resources in required. Detailed consideration of this definition, however, brought further interesting facets to light.

First, a destructive event: Civil disturbances may account for a large number of victims yet are not necessarily destructive in the sense that a great deal of material damage is caused.

1. THE EFFECT ON THE SURROUNDING COMMUNITY:

simple(1) ———————————— compound (2)

2. DISASTERS CLASSIFIED ACCORDING TO ORIGIN

Man-Made (0)		**Naturally Occurring(1)**
Traffic		Fire
Explosion		Earthquake
Structure collapse		Hurricane, tornado
Fire		Volcanic eruption
Panic		Avalanche, mud slide, land slide
Civil disturbance		Meteoric collision
Nuclear accident		Drought
Poison gas		↓
Local wars →	(Refugees) →	Famine
		↓
		Epidemic

The majority of disasters give rise to victims with mechanical (including thermal) traumata: wounds, sprains, bleedings (internal/external), fractures, dislocations, concussions and organ damages. The minority of disasters results in chemical, nuclear and microbial lesions.

Second, the medical resources: These can also be defined and assessed, although the availability and stage of development of such services is not universally the same, they nevertheless exist.
Third, casualties: Although in fact the number of injured is known, the real concern is the relationship between the number of casualties and the potential of the resources available. Even a serious explosion or fire need not be a disaster in the presence of adequate facilities for rescue and treatment.
Since the medical resources could not only increase their treatment capacity by extra mobilization, but also by optimizing their own disaster preparedness, the definition was adapted later into: "A disaster is a destructive event that causes a discrepancy between the number of casualties and their treatment capacity". The breaking-point is indicated by the medical severity index and is described in the next chapter. The algorithm of the latest conception mentioned is shown in the figure.
From the above it would appear that disasters may be classified, and at the same time graded or scored, according to:

1 The effect on the surrounding community, with further differentiation into a simple effect and compound effect.
   In fact, the occurence of a disaster and the response thereto, in the form of initiation and coordination of the rescue services, are intimately associated with each other. In the case of a simple disaster, the integrity of the surrounding community remains intact, and the (extra) resources of the local and regional rescue services prove adequate to deal with the situation. Should a compound disaster occur, in which case the resources available locally and regionally are unable to cope alone, the involvement of national and international organizations is required. A rail-traffic accident involving a passenger train in a West-European country might be given as an example of a simple disaster whereas an earthquake in a densely populated region of North Africa could give rise to a compound disaster. A simple disaster is accorded a score of 1, whereas a compound disaster receives a score of 2.

2. The cause: In this case, a differentiation is drawn between naturally occurring and cultural (man-made) disasters. Man-made disasters are generally less complicated and more confined than natural disasters, for which reasons cultural disaster are accorded a score of 0 and the natural sort a score of 1. Of course, a major war could be an exception to this general rule.

3 The duration of the cause

< 1 hour (0)
1 - 24 hours (1)
> 24 hours (2)

4 The radius of the disaster area in which casualties have fallen.

< 1 km (0)
1 - 10 km (1)
> 10 km (2)

5 The number of casualties dead and wounded requiring medical treatment

< 100 (0)
100 - 1000 (1)
> 1000 (2)

6 Average severity of the injuries sustained:

$$S = \frac{T1 + T2}{T3}$$

0	1	2
$T1 + T2 \ll T3$	$T1 + T2 \approx T3$	$T1 + T2 \gg T3$

3. The duration of the cause of disaster: This can be short (less than 1 hour), relatively long (1-24 hours), or long (more than 24 hours). The majority of simple disasters occurs instantaneously, while compound disasters are usually characterized by a longer initiation time (eg, earthquakes, famines, epidemics). The subdivision into short, relatively long, and long is arbitrary and may have to be revised. The subdivisions are given scores of 0, 1 and 2 respectively.

4. The radius of the disaster area: This can be small (less than 1 km), relatively large(1-10 km), or large (more than 10 km).
   From a medical viewpoint, the disaster area implies that area in which casualties have fallen. It is not, therefore, that area characterized by damage, for example, broken glass. Scores of 0, 1 and 2 are accorded, respectively.

5. The number of casualties (N): An arbitrary division of the number of casualties is made as follows:

minor:	25-100 casualties, dead and wounded, requiring medical treatment;
moderate:	100-1000 casualties, dead and wounded, requiring medical treatment;
major:	more than 1000 casualties, dead and wounded requiring medical treatment;

   Even a few casualties may give rise to enormous problems to unprepared communities, whereas large numbers of injured may hardly exhaust resources that are adequate and well-organized. The casualties requiring admission to hospital form, from a medical point of view, the crucial group; the dead and slightly injured, who do not require inpatient treatment, are, in this respect, less important. The groups are graded with scores of 0, 1, and 2, respectively.

6. The average severity (S) of the injuries sustained by living victims: The usual distribution of injuries sustained is given as serious 10%, moderate 30% (both groups requiring hospitalization) and light 50% (10% dead). Should there be a relatively large number of slightly injured or sick, requiring no hospitalization, a score of 0 is accorded; otherwise, in the usual case a score of 1 is given. On the other hand, should the disaster result in a relatively large number of seriously injured or very ill a score of 2 is accorded.

7. **The medical rescue time: rescue, primary treatment, transportation**
< 6 hours (0)
6 - 24 hours (1)
> 24 hours (2)

DISASTER SEVERITY SCALE

Scale	Location	Cause	Date
12	Armenia (USSR)	Earthquake	1988
11	The Netherlands(NL)	Floods	1953
10	Bhopal (India)	Poisonous gas	1984
9	Mexico City (Mexico)	Earthquake	1981
8	Texas City (USA)	Explosion	1947
7	Tenerife (Spain)	Traffic	1977
6	Piper Alpha (UK)	Explosion	1988
5	Los Alfaques (Spain)	Explosion	1978
4	Zeebrugge (B)	Traffic	1987
3	Beek (NL)	Explosion	1975
2	Prinsenbeek (NL)	Traffic	1972

7. The time required by the rescue organizations for initiation of primary treatment,organization of transport facilities, and evacuation of the injured could be short (less than 4-6 hours), relatively long (6-24 hours) or long (more than 24 hours).

   In the case of a compound disaster in such an area, the primary treatment time will be that time required for the institution of the most urgent first-aid measures at the site, followed by definitive medical treament. The score allocation is therefore arbitrary and may require revision according to the particular circumstances. The subdivisions are graded with a score of 0, 1, and 2, respectively.

Thus, by attributing to the individual classification a grade of 0, 1 and 2, the score itself increasing with gravity, duration, number, or intensity, a figure is obtained which is the sum of the variously accorded scores and which lies between 1 and 13. This scale is called the Disaster Severity Scale (DSS). In order to avoid scale 0, the options of classification 1 were chosen as 1 and 2, instead of 0 and 1.

The DSS was tested by subjecting a number of disasters to a retrospective study. The table shows how assessment of these disasters in this way bore a reasonable similarity with the factual occurence. Two examples may explain the compilation of this table.

The Armenian earthquake in 1988 was a compound disaster (score 2), of natural origin (score 1), the duration of the cause was relatively long (score 1), the radius of the disaster was more than 10 km (score 2), the number of casualties amounted to 50,000 (score 2) with many seriously wounded victims (score 2), while the time required by the rescue organizations was long (score 2). Summation of the individual score resulted in scale of 12.

The Prinsenbeek disaster in 1972 on the other end of the scale was a simple one (score 1), of man-made origin (score 0), the duration of the cause was short (score 0), the radius of the disaster area was small (score 0), the number of casualties requiring hospitalization amounted to 100 (score 1), with a "normal" distribution of categories (score 1), while the time required by the rescue organization was short (score 0). Summation of the individual scores resulted in a scale of 3.

BASICS of DISASTER MEDICINE

Definition

Classification

1 simple ↔ compound
2 man-made ↔ God-made
3 duration of cause
4 radius of impact area
5 number of victims (N)
6 severity factor (S)
7 rescue, primary treatment and transport time

Scoring

disaster severity scale

Discussion

Disaster medicine studies the medical and organization problems of disasters. It is a young branch of medicine and confusion still occurs because people use terms in different ways. The foundation of any science is definition, classification and measurement, and if disaster medicine is to grow and progress, it also must have a consistent and recognized definition, classification, and measurement of disasters. By using the criteria "casualties" and "discrepancy between number and treatment capacity" a simple definition of a disaster has been formulated. The classification scheme is based on variables, which are directly related to disaster, either to its origin or to its effect. By quantifying or weighing these variables and summing the individual scores, a disaster severity scale can be constructed, which runs from 1 to 13. This approach could provide a firm foundation for the science of disaster medicine, on which basis further development can be confidently expected.

In the event of general international agreement on the definition, the classification, and the associated Disaster Severity Scale, it should be possible to assess more accurately the gravity of a given situation. However, the publication of exact figures exposes cooperating countries to the possibility of criticism. For this reason, there may be initial resistance on the part of certain countries to joining such a registry scheme. This reservation should be overcome if exact disaster registration is to be established. Additionally, more precise registration would allow scientific comparison of disasters and perhaps also provide an answer to the question of whether the incidence of disaster occurence is increasing with the growing world population and technology.

A limitation of the practical use of this scoring system is that it can only be applied retrospectively. For this reason the medical severity index had been introduced and will be discussed in the next chapter. This index not only indicates the breaking point between accident and disaster, but also quantifies the medical severity instantaneously.

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Definition

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THE MEDICAL SEVERITY INDEX OF DISASTERS*

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF EMERGENCY MEDICINE (1989)

Single event		Mass casualty
no discrepancy accident	transition point of discrepancy	discrepancy disaster

↓

Directly proportional to:	number of casualties and average severity of injuries	(N) (S)
Inversely proportional to:	treatment capacity in the chain of medical care	(C)

In 1980 an international working party postulated a definition for a disaster. Later de Boer and Rutherford utilized this concept and created a classification and scoring system. A limitation of the practical use of this system was that it could only be applied retrospectively to the comparison of different events. It was therefore decided to modify this system in a way that would make it of use during the management stage, while a disaster was still actually in process. According to Brismar the definition was modified, and on the basis of the number of casualties and the severity of injuries sustained, a medical severity index was created.

In this way an instant score could be obtained in order to calculate the response required by the medical emergency services. In the following the methodology is explained.

METHODOLOGY

From a medical point of view a disaster can be defined as a destructive event that causes so many casualties that a discrepancy occurs between their number and treatment capacity.

Considering this definition, the parameters needed to quantify a disaster are the casualty load (number of casualties), the severity of incident (severity of injuries sustained), and the capacity of the medical services.

ESTIMATING NUMBERS OF DISASTER VICTIMS

Basic figures for contingency planning

IMMOVABLES			RANGE[1]
Residential area[2]	Per hectare	Low-Rise Buildings High-Rise Buildings	20-50 50-200
Business area	Per hectare		0-800
Industrial area	Per hectare		0-200
Leisure area	Per type	Stadium Discotheque Camping-site	-[7] - -
Shops	Per type	Department store Arcade	-[7] -

MOBILE OBJECTS			RANGE[1]
Road transport	Per 100 M (length)[3a] Per type[3b]	Multiple collision Coach	5-50 10-100
Rail transport[4]	Per type	Single deck Double deck	5-400 10-800
Air transport[5]	Per type	Small Large	10-30 150-500
Inland Shipping[6]	Per type	Ferry Cruise ship	10-1000 200-300

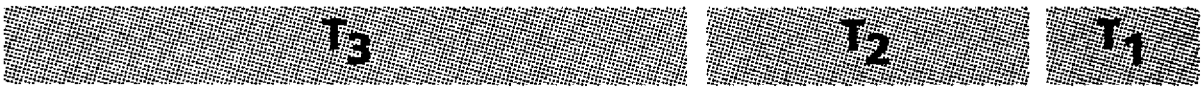
1 depends on date, time and other local circumstances.
2 combination of number of residents per house (1.8-2.8) and number of houses per hectare (30-70).
3a per car: lenght 5m and 1.5-3 passengers (see 1).
3b (articulated) local bus or (articulated) double-deckerbus.
4 carriages of 3 or 4 wagons (see also 1).
5 seat occupancy 70%.
6 seat occupancy 80%.
7 awaiting further research.

Casualty load (N)

When the ambulance control receives the first notification, it may be difficult to make anything but the most tentative guess at the number of casualties to expect. In minor to moderate disasters such as transport accidents, the size of the coach or train as well as the type of accident (e.g., head-on collision of train, of coach or derailment) may give an upper limit of casualties. The original estimate by a member of the public who reports always tends to be overestimated (Rutherford's Rule). The dispatcher will respond by sending some ambulances to the site and will then receive a revised estimate from someone inside the system. While this figure often has to be modified later as casualties start being identified, sorted, and transported, it is good enough for the first calculation, and can be designated as N. The controller should then attempt to keep track of the numbers of casualties being cleared from the site. In major disasters like earthquakes, early reports describe a single fragment of a much larger situation and tend to be underestimated (Rutherford's Rule). Therefore it is necessary to send a mobile (preferably airborne) medical unit to survey the whole stricken area and assess the magnitude and nature of damage, the number of casualties, and their location. Subsequent estimates made at intervals of 1 hour, 2 hours, 3 hours, etc., are to be designated as N1, N2, N3, etc. These estimates should than fit in the ranges as provided by empirically determined tables. These estimates are based on Rutherford's Rule. For further reading see one of the next chapters.

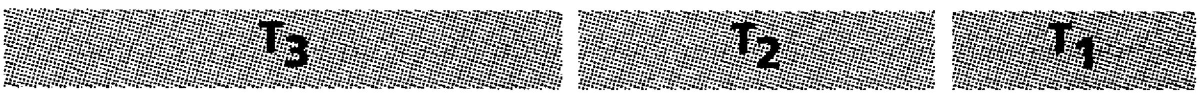
$$S = \frac{T_1 + T_2}{T_3}$$

S = 0 - 1 many slightly injured



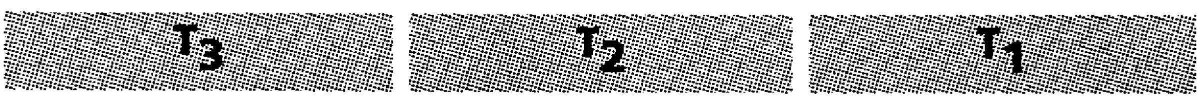
$T_3 > T_1 + T_2$ civil disturbance, hurricane

S = 1.0 "normal"



$T_3 \sim T_1 + T_2$ traffic accidents

S = 1 - 2 many severely wounded



$T_3 < T_1 + T_2$ fires, explosions

← total number of victims →

Theoretically S varies between O and ∞
Practically S varies between 0.5 and 2.0

Severity of Incident (S)

The severity of incident may be represented by the symbol S. Although alternative methods of classification of injured are possible, casualties can be divided, from a medico-organizational point of view, into 4 categories: 4-dead and the dead-on-arrival (DOA); 1-life threatening cases demanding immediate attention; 2-non-life-threatening cases requiring hospital treatment; 3-casualties not necessarily requiring hospitalization but rather less demanding single point care.

Since category 1 and 2 casualties are those who need medical attention by professionals, those who have to be transported to hospitals by ambulances, and those who have to be admitted to hospitals, they form the crucial group-crucial because any delay in treatment result in more dead and dead-on-arrival, while the condition of the remaining injured deteriorates.

It is known that in most fires and explosions, categories 1 and 2 comprise more than 50% of the total number of casualties, while civil disturbances, on the other hand, usually result in many slightly wounded and a few heavily wounded.

Therefore, it would seem that deviation to either side of seriousness occurs depending on the type of disaster and possibly some other factors, like population at risk, site where the disaster took place, and the time of occurence. Thus S is expressed as $\frac{T1 + T2}{T3}$

If many seriously wounded casualties (categories 1 and 2) are to be expected, S is scored between 1.0 and 2.0. If only many slightly injured are to be foreseen S is scored between 0.0 and 1.0. Some disasters usually result in a figure between these extremes, and therefore S can be indicated as around 1.0. This forms the basis for scoring the medical severity of the incident.

In the chapter on Epidemiology the results of an analysis of more than 400 disasters is shown.

The Medical Rescue Capacity (MCR):

the number of victims that could receive Basic or Advanced Life Support per hour;

The Medical Transport Capacity (MTC):

the number of victims that could be transported to hospitals per hour;

The Hospital Treatment Capacity (HTC);

the number of victims that could be treated in a hospital per hour.

The lowest capacity in the chain of medical care determines the capacity of the whole chain.

The total capacity TC is determined by the number of hours the lowest capacity in the chain can proceed.

Capacity of Medical Services

Progressive medical care of disaster casualties is a concept of aid appropriate to the needs of the individual at any given time, beginning at the disaster site and continuing through the transportation and distribution phase to the period of the definitive therapy in hospital. Thus, the capacity of medical services is divided into three phases. Medical care at the site, or medical rescue capacity (MRC), depends on the amount of professional medical help at the site and can be expressed as the number of T1 and T2 victims which can be treated per hour by experienced doctors, nurses, and paramedics plus material and equipment available at the disaster site. The doctors, nurses, and paramedics usually work as a team, and the team is assisted by first aiders. It is assumed that a team, comprising a surgeon, an anaesthesiologist, and two nursing staff can deal with 8 casualties categories 1 and 2 per hour, provided again they are afforded the support of personnel and equipment. Under abnormal conditions, say difficult terrain or bad weather this number will be fewer than 8. Medical transport and distribution of casualties, categories 1 and 2, to and among hospitals, or the medical transport capacity (MTC) depends on the number of ambulances with drivers, the ease of evacuation, and a patient distribution scheme. Such a scheme is based on the capacities of the surrounding hospitals and their special expertise, like neurosurgery and cardiovascular surgery. This MTC can also be expressed in number, for which a formula is introduced recently. Medical treatment in the hospital, or the hospital treatment capacity (HTC) depends on the total number of surgeons, anesthesiologists, operating rooms, intensive care beds, residents, and the like. The HTC refers to the number of casualties (categories 1 and 2) that can be treated according to normal medical standards in one hour. If the disaster takes place at night or on the weekend, the HTC will be lower than the HTC during the morning of a weekday. As a rough figure, obtained empirically through many exercises held at hospitals of different sizes, a HTC for general hospitals can be estimated as 3% of the total number of beds.

$$\frac{N \times S}{TC}$$

$$N \times S < TC \quad \text{accident}$$

$$N \times S > TC \quad \text{disaster}$$

Category 3 casualties frequently consult their local or private doctor or are spontaneously transported to the nearest hospital by private cars. Thus the nearest hospital to the disaster site is often overloaded with category 3 casualties and should preferably be excluded from category 1 and 2 casualties.

All the capacities mentioned are based on a "normal" situation of roads, weather, and working hours. If the terrain is difficult, the weather is bad, or if the disaster takes place at night or on a holiday or weekend, then the capacities are lower than under "normal" conditions. If, on the other hand, the roads are perfect, the weather is bright, and the disaster takes place on a weekday, out of season, and in the morning, the capacities are higher than under "normal" conditions. The capacities are expressed per unit of time, that is, per hour.

Under disaster conditions, doctors, nurses, ambulance drivers, first aiders, and others can probably work efficiently for 8 hours at the most. Again this is an assumption, because after 8 hours of hard work by all personnel, fatigue and lack of material most likely will decrease the HTC considerably. Therefore, the capacities should be multiplied by 8 in order to obtain the total capacity (TC) of the medical services for a realistic period of time. Following a few hours of rest and the provision of new stocks the capacities could increase again. For calculation purposes, however, this unit (TC) is probably the best one to use.

In order to avoid stagnation during this chain of events, synchronization of MRC, MTC, and HTC is imperative, which implies that these capacities should be equal to one another.

One could have a situation with a large HTC but a small MTC, then the small MTC is determining the proper functioning of progressive medical care. Thus the lowest capacity determines the capacity of the whole chain.

For further reading see also the appropriate chapters.

A Retrospective Study of a Number of Calamities[a]

	N	S	TC[b] district/region	N x S / TC	
1973 Harfsen (car traffic)	20	1.0	24	20x1 / 24	= 0.8
1972 Prinsenbeek (car traffic)	30	1.0	65	30x1 / 65	= 0.4
1962 Harmelen (railway accident)	150	1.5	90	150x1.5 / 90	= 2.5
1975 Beek (explosion/fire)	90	1.5	200	90x1.5 / 200	= 0.6
1978 San Carlos (explosion/fire)	150	1.5	30	150x1.5 / 30	= 7.5
1977 Tenerife (air traffic acc.)	500	1.5	100	500x1.5 / 100	= 7.4
1953 Netherlands (floods)	1850	1.5	540	1850x1.5 / 540	= 5.0
1976 Guatamala (earthquake)	100.000	1.5	1000	100.000x1.5 / 1000	=150

a) As can be seen, the traffic accidents in Harfsen and Prinsenbeek and the explosion/fire in Beek cannot be considered as a disaster according to the criteria used.

b) Rough estimates.

N.B.: At the time this table was produced (1989) the S-factor has not yet been verified, as shown in the next chapter (1997).

MEDICAL SEVERITY INDEX

Once the casualty load (N), the severity of incident (S), and the total capacity (TC), of the medical services (MRC, MTC, and HTC) are quantified, the medical severity index $\frac{(N \times S)}{TC}$

can be defined. If N x S exceeds the local, total capacity of medical services (medical severity index > 1), problems will arise, and the calamity is called a disaster. This can be illustrated by the following example. A heavy explosion in a chemical plant occurs at night in a remote area during bad weather with an expected number (N) of categories 1 and 2 casualties of 230. Explosions usually give rise to many heavily wounded, therefore S will be scored as 1.5.

If three hospitals are located in this area, with 90, 140 and 180 beds, respectively, then the HTC altogether amounts to 12 (3% of (90 + 140 + 180)). For an 8-hour period the total capacity TC will be 96 (8 x 12). Because of the abnormal situation of roads, weather, and nighttime, fewer than 96 casualties can be dealt with, say 85. Thus, $\frac{N \times S}{TC} = \frac{230 \times 1.5}{85} = \frac{345}{85} = 4$

which is larger than 1, so the county cannot cope with this calamity, and assistance of neighbouring counties is necessary. Therefore, this calamity is called a disaster. By applying this model retrospectively to a number of calamities that occurred in the last decades, the methodology was tested as shown in the table. The total capacities applied are only rough estimates, since accurate figures of the number of beds, surgeons, anesthesiologists, and so forth are difficult to obtain, but approximate the kind of information that would be available in the midst of a crisis situation. As can be seen from this table, not all calamities could be classified as disaster because N x S did not exceed the total capacity of the medical services in these particular districts, regions, or counties.

MSI could be applied:

1. for the disaster itself
2. for estimating the medical requirements in the disaster preparedness phase

Discussion

The proposed methodology will be of practical importance when handling disaster situations. When a dispatcher at the fire station, the police station, or the central ambulance post, receives a call reporting a calamity, it is most often possible to estimate the number of casualties by utilizing a few key questions. With experience and a knowlegde of the local situation the dispatcher can make a rough estimate of N, S, and TC and calculate the medical severity index. Thus the methodology offers the dispatcher a rapid instrument to estimate if a calamity should be called a disaster or not, that is to say, if the total local medical capacity will be sufficient or not to cope with the casualty load and severity of incident. The number of trauma teams and stand-by ambulances as well as the treatment capacity of surrounding hospitals should be well-known figures. All these factors must be updated periodically in order to keep MRC, MTC, and HTC synchronized. In this way the chain of progressive medical care from disaster site to hospital can be streamlined. For example the centralization of emergency medical care by closing down smaller emergency departments (increasing the distance to hospitals and thereby reducing the MTC) has to be counteracted, for example, by creating an ambulance helicopter service. Otherwise there will be an imbalance between the three links in the chain of capacities. In the same way, the need for trauma teams can be expressed in order to increase the MRC. Thus, in different ways, synchronization of the three links in the chain of capacities could be obtained. The methodology described could be of importance, not only for the disaster situation itself, but also in the disaster preparedness phase for estimating the requirements needed to produce a desirable capacity within the various links in the chain of progressive medical care from the disaster site to the hospital.

EVALUATION OF DISASTERS*

* ADAPTED FROM AN ARTICLE IN THE EUROPEAN JOURNAL OF EMERGENCY MEDICINE (1997)

CLASSIFICATION	GRADE	SCORE
effect on infrastructure (impact site + filter area)	simple	1
	compound	2
man-made versus God made	man-made	0
	God-made	1
impact time	< 1 hrs	0
	1-24 hrs	1
	> 24 hrs	2
radius of impact site	< 1 km	0
	1-10 km	1
	> 10 km	2
number of casualties (N) (dead and wounded)	< 100	0
	100-1000	1
	> 1000	2
average severity of injuries sustained (S)*	< 1	0
	1-2	1
	> 2	2
rescue time (rescue + first aid + transport)	< 6 hrs	0
	6-24 hrs	1
	> 24 hrs	2
Total	**DSS**	**1-13**

$$*S = \frac{T_1 + T_2}{T_3}$$

Introduction

Since the number of particularly man-made disasters is rising significantly epidemiologic research is imperative. Epidemiologic research however of disasters is hampered by a lack of uniformity and standardization of describing these events. Recently, however, a definition, classification and scoring system, with an emphasis on the medical aspects, became available. This system could be utilized as a tool for evaluating disasters. First of all the event should be caracterized as a disaster by applying the two criteria : are there victims and is there a discrepancy between number and medical treatment capacity of these victims? Than a classification, utilizing seven parameters, is imposed. These parameters are: the effect on the infrastructure in the disaster area, man-made versus God-made, the impact time, the radius of impact site, the number of casualties, the average severity of the injuries sustained by the living victims and the rescuetime. These parameters are shown in detail in the table.

By attributing to the indvidual classification a grade 0, 1 or 2, the score itself increasing with gravity, duration, size, number or intensity, a figure is obtained which is the sum of the variously accorded scores and which lies between 1 and 13. The scale is called the Disaster Severity Scale (DSS).

With the aid of this methodology epidemiologic research might be feasible, while certain aspects of disasters can be compared to one another.

This chapter describes the attempts to evaluate some hundreds of disasters, again with an emphasis on the medical aspect. Only in this way could the methodology be tested. Some minor modifications are proposed for reasons of simplicity.

MAN-MADE		p	q
traffic	air	51	7
	road	6	4
	train	21	5
	sea	11	2
explosions		19	5
terrorism		121	19
fires		20	4
riots		62	5
panic		7	1
chemical		15	3
nuclear		2	2
TOTALS		**335**	**57**

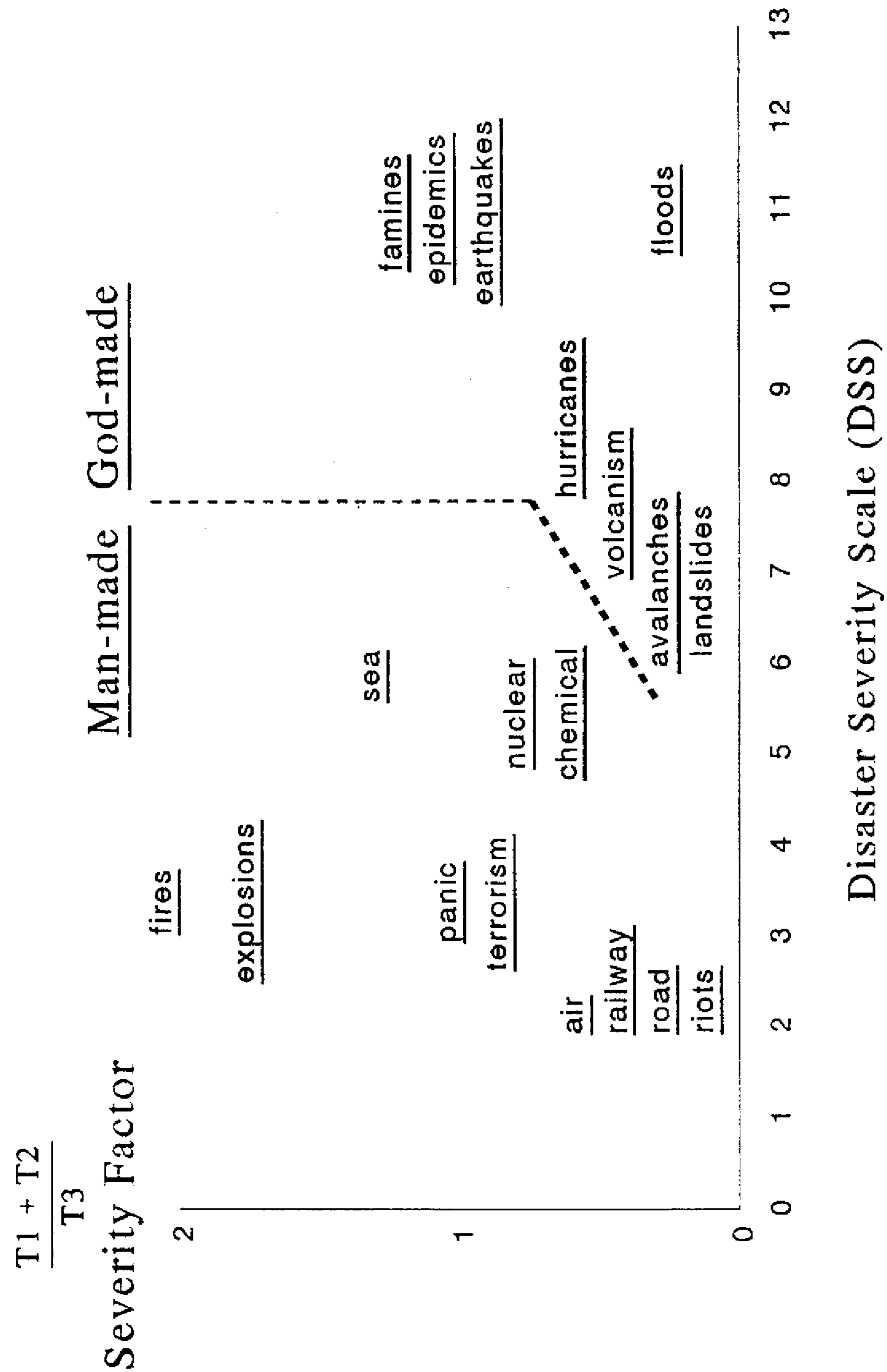
GOD-MADE	p	q
earthquakes	31	7
floods	15	3
hurricanes	14	5
volcanism	4	1
avalanches/landslides	8	2
famines	3	1
epidemics	6	3
TOTALS	**81**	**22**

p: number of references
q: number of useful references

Material and Methods

In a previous paper a definition, classification and scoring system for disasters has been described. By applying this methodology, an analysis could be performed of more than 400 disasters, which occurred in the last 40 years. The necessary data were obtained from the literature and from historical yearbooks. The disasters were divided grossly into naturally-occuring and man-made ones. A further division was made into various types as shown in the table.
Not all parameters necessary to perform the scoring for the Disaster Severity Scale could be traced in the literature references. In these cases as many additional literaturereferences as possible were acquired in order to complete the classification and scoring. When this was at all impossible the disaster was eliminated as such.

In order to obtain a reliable measure of the average severity of the injuries sustained the severity factor S was utilized expressing the ratio between T1 + T2 and T3 victims or those victims who were hospitalized and the non-hospitalized ones. Particularly, the search of this S factor was difficult to perform and as a consequence the majority of references could not be used for a reliable scoring. Only a minority of references resulted in a sufficient number of each type of disaster from which some preliminary results could be obtained.



DSS versus S for man-made and God-made disasters.

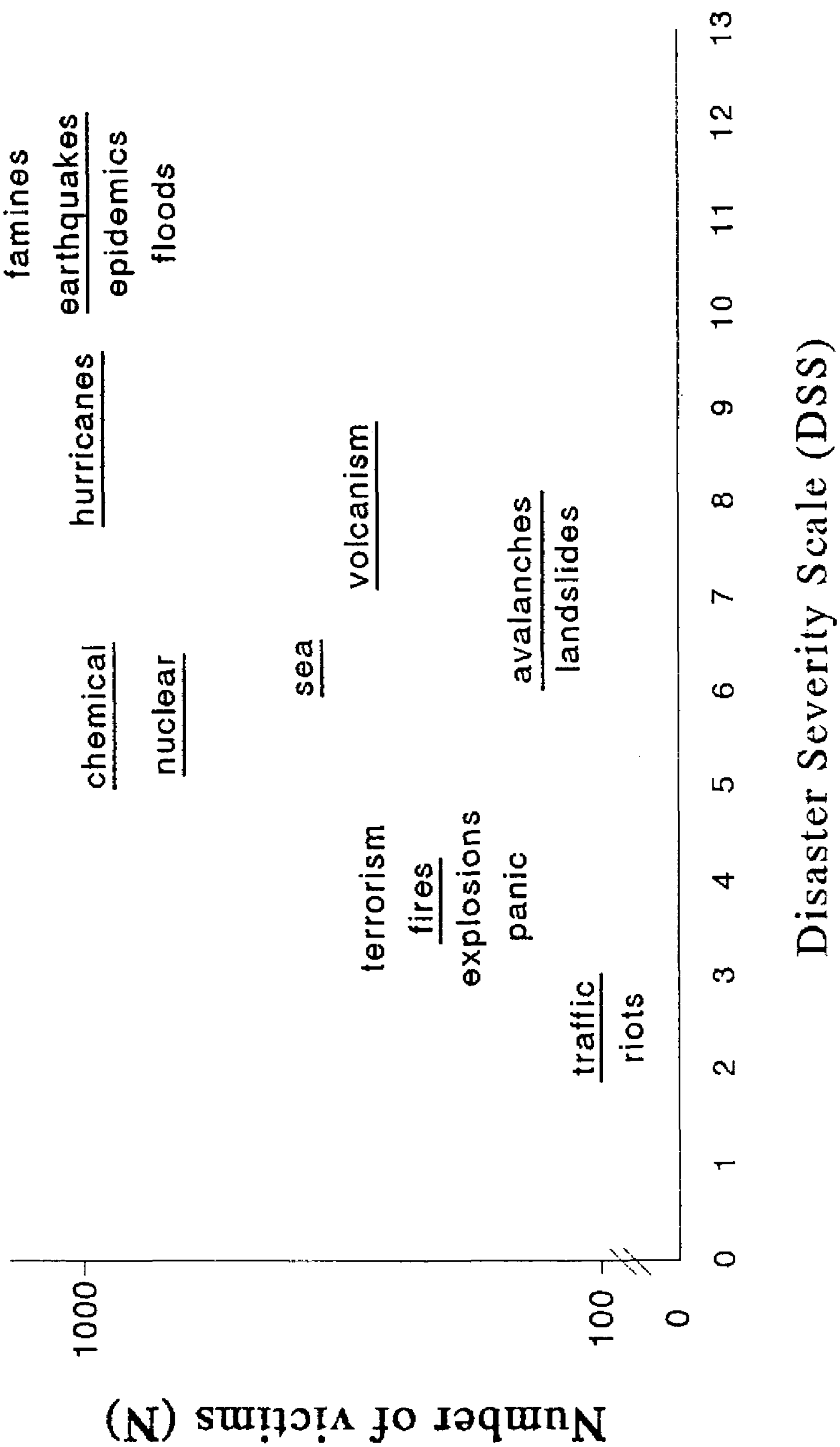
RESULTS

As shown in the table 57 out of 335 references were useful for determining the disaster severity scale for man-made and 22 out of 81 references for God-made disasters.
Since the number of each type of disaster was too small for most types to perform any statistical analysis, the man-made and God-made disasters were clustered and compared. However, aircrashes, terrorism, riots and earthquakes provided enough numbers to perform an individual analysis.
Furthermore, the disaster severity scale of the usefull references were plotted against the severity factor S, which is the ratio between the hospitalized and non-hospitalized casualties. This was also done against the number of victims, dead and injured (N). Both graphs are shown.

SOME EXAMPLES MAY ILLUSTRATE IN DETAIL THE METHODOLOGY UTILISED.

The air crash of a cargoplane on an appartmentbuilding in the outskirts of Amsterdam on a sundaynight (1992) did not affect the infrastructure (1), was a man-made disaster (0), the time while the crash was operating was very short (0), the radius of the area where victims were located, was small (0) the number of victims dead and alive was set at 65 (0), the severity of the injuries sustained or T1 + T2 versus T3 amounted to (1) and the time for medical rescue operations took less than a day (1). This disaster was therefore scaled as 3.

The hurricane which hit the island of St. Maarten in the Carebean (1995) took place on wednesday and did affect the infrastructure (2), was a natural disaster (1). The impact-time took many hours (1), the radius of the area where victims were located was several kilometers (1), the number of victims, a few dead, many slightly wounded and some severely injured was set for some hundreds (1) and therefore the ratio T1 + T2 versus T3 amounted to (0), while the medical rescue time took more than a day (2).
This disaster was scaled as 8.



DSS versus N for man-made and God-made disasters.

Conclusions and discussion

Disasters have always frightened people, on the other hand they have intrigued them too. Each disaster yealded dozens of stories, the majority of which described the horrors only.

In 1983 a definition and classification was proposed and in 1990 a scoring system for disasters was added to it, which could be utilized to standardize the description of these events. And this in turn could lead to epidemiologic studies. This paper is an attempt to study the usefulness of this system as a tool for evaluating disasters. From the references traced only a minority could be used to obtain the necessary parameters to produce a scale. For hurricanes, terrorism and aircrashes data were found in some excellent review articles, which could either confirm or readjust the findings.

For each type of disaster a range on the Disaster Severity Scale was determined. In other words types of disaster are clustered in such a way that man-made disasters are varying between 1 and 6, while God-made disasters are scaled between 6 and 13 on the disaster severity scale.

Also, the same types of disasters were related to the severity factor S, which is the ratio between the hospitalized and non-hopitalized victims. As can be seen from the figure fires and explosions give rise to many seriously wounded victims who need hospitalization. On the other hand riots, avalanches/landslides, floods and to a lesser extent also traffic result in many slightly wounded as compared to those who have to be hospitalized. Finally, the same types of disaster were related to the number of victims, dead and wounded, N. As shown in the figure the

CLASSIFICATION	GRADE	SCORE
effect on infrastructure (impact site + filter area)	Simple	1
	Compound	2
impact time	< 1 hrs	0
	1-24 hrs	1
	> 24 hrs	2
radius of impact site	< 1 km	0
	1-10 km	1
	> 10 km	2
number of dead	< 100	0
	> 100	1
number of injured (N)	< 100	0
	100-1000	1
	> 1000	2
average severity of injuries sustained (S)*	< 1	0
	1-2	1
	> 2	2
rescue time (rescue + first aid + transport)	< 6 hrs	0
	6-24 hrs	1
	> 24 hrs	2
Total	**DSS**	**1-13**

$$*S = \frac{T_1 + T_2}{T_3}$$

highest numbers were seen in famines, earthquakes, epidemics, hurricanes and floods; the lowest in traffic accidents (road, train, and air) and riots.
The problem encountered in analyzing the useful references was the lack of standardization in the description of victims: number of dead, of seriously wounded and hospitalized, of the non-hospitalized wounded and of the non-wounded.

Nevertheless, the useful references showed at least the possibility to obtain in an standardized way a score of the disaster. Most types of disaster could thus be scaled by applying the classification scheme as proposed in 1990. During this investigation, however, it became clear that the parameters "effect on infrastructure" and "man-made versus God-made" are identical, because naturally occurring disasters are so severe that they always lead to a compound effect on infrastructure. Moreover, a separate parameter "number of dead" should be introduced, since a number of disasters only lead to dead without wounded.
Therefore, a slight modification of the classification scheme is proposed by deleting "man-made versus God-made", introducing "number of dead", and changing "the number of victims" into "number of injured". The number of dead should then be graded <100=0; and >100=1. In this way, the scale itself still runs from 1 to 13. The proposed classification is shown in the table. Utilizing this modified classification and scoring system did not alter the results very much.

FIRST ACTS AT THE DISASTER SITE
for doctors, nurses and paramedics

A C T T T !

Anticipation

measures to be taken in order to protect

yourself
others
victims

Control

S U R V E Y nature
size
victims

A L A R M

P A N I C C O N T R O L

Doctors, nurses and paramedics are educated and trained to help any patient in need. However, should they be involved in a mass casualty situation the approach is different; because of scarcety in personnel, material and methods. This implies that priorities should be set in order to save as many lives as possible under these circumstances.

The first act, therefore, is the anticipation of escalation. This is achieved by taking those measures to protect yourself first (a dead doctor, nurse or paramedic is of no use!) than others and finally the victims. This means that a certain switch has to be taken in the minds of these people, whose attitude towards the individual patient is purely altruistic. Being confronted with a mass casualty situation, doctors, nurses and paramedics, are inclined to approach the first screeming victim they encounter. Under these circumstances, however, this is a blunder!

Following anticipation some control measures must be taken. First of all a survey of the situation: the nature, extent and estimate of the number of victims. Secondly, this information should reach the "outside world" as quickly and as reliable as possible. Thirdly, panic should be prevented at all cost.

AIRWAY
BREATHING — VITAL FUNCTIONS
CIRCULATION

CONCIOUSNESS	FRACTURES
HEMORRHAGES	BURNS
WOUNDS	HYPOTHERMIA

TRIAGE

trier = french for sorting

= classification of casualties according to the injuries sustained.

T1
ABC instability
immediate life support
(urgent hospital treatment)

T2
ABC stable
to be treated within 4-6 hours,
otherwise ABC instability
First-aid measures
Hospital admission

T3
ABC stable
minor injuries, not threatened by ABC instability
Can be treated by general practitioners

The next act at the disaster site for the first arriving doctor, nurse or paramedic should then be a so called sweeping triage: a quick round in order to locate those who are in urgent medical need. Following this sweeping triage, either a second round should be made, or first-aid measures should be given to those who have been classified as T1. This decision depends on the availability of more doctors, nurses and paramedics rushing in at the scene of disaster. When they are available in the meantime, the first should continue their/his/her triage, while others perform first-aid. If not available the first should start provisional treatment of the T1 victims.

It is likely that a severely injured victim (T1) will not screem or holler, while T2 and T3 victims will draw anyone's attention, especially from the rescuers. Non-wounded relatives of slightly hurt victims will do the same. It is a well-known experience that those relatives are sometimes capable of forcing ambulance crew to drive a T3 victim to hospital. There are also stories of ambulances being hijacked by them.

Triage itself is a very difficult medical process, even a well experienced surgeon-traumatologist could have difficulties with it; not only emotional, but also technical and managerial aspects will continiously influence the decision-making process of triage.

This repeated process in the chain of medical care should be a uniform one: from the disaster site to the hospital bed.

An example of such a triage methodology, which can be applied for mechanical (including thermal) and chemical types of injury and which can be utilized in the entire chain of medical care, is shown here.

The only critirion being used is time: T1 victims with disturbances of vital functions need medical help within one hour, the so called golden hour, otherwise the whole T1 group will be eliminated within a couple of hours. T2 victims need first-aid measures at the site with subsequent treatment in hospital, preferably not exceeding more than 4-6 hours otherwise complications are introduced which are irreversible. For further reading see the appropriate chapter.

FIRST-AID MEASURES

- Positioning: prone, supine + legs-up, stable side position, sitting and Trendelenburg
- elimination airway obstruction
- cardio-pulmonary resuscitation
- hemorrhage control
- wound care
- fracture immobilisation
- psychological approach

The next act is a first-aid treatment, which must be provided in an orderly manner. Without any supportive means, like drips, tubes, ventilators or medicines much can be done if properly trained.
Firstly, the victims should be positioned in an appropriate way, whereby the stable side position is meant for unconcious patients in order to prevent aspiration when vomiting. The sitting position is particularly relevent for thoracic injuries, while the supine position with the legs up could be utilized for victims with shock. The latter, however, should be done with caution, since this may lead to adverse effects. Drowning cases have to be positioned in a Trendelenburg manner when feasible. Following the positioning the first-aid measures proper are to be taken.
Without any supportive means certain measures can still be taken, like elimination of airway obstruction, where a proper positioning may improve already patient's condition. Whether or not cardio-pulmonary resuscitation has to be applied depends on the availability of medical personnel. In a mass-casualty situation with a shortage of medical personnel cardio-pulmonary resuscitation is time consuming and should therefore be left-out. On the other hand, hemorrhage control with the application of pressure by any means on the right place is simple and can be done quickly. The same holds for wound care and fracture immobilization. All these techniques are described extensively in first-aid manuals and will not be discussed any further.

- carrying techniques
- transport by ambulance, car, heli, airplane, train, ship
- immobilisation of drips
patient
fractures
- pain relief
- psychological approach

A C T T T

The final act now is transportation of the victim from the site to any musterpoint, where ambulances are able to load them. Certain carrying techniques by one, two or more persons, with or without the use of strechers, have to be utilized before the victim can be transported by other means, like ambulances, cars, helicopters, planes, trains or ships. These techniques are usually also described in first-aid manuals. Transporting patients means the immobilization of drips, fractures, and even the patient himself. Of course pain relief is of importance, particularly when long distances have to be covered in which case long-acting analgesics should be administered. The administration of these drugs, however, is contraindicated in the presence of head, chest and abdominal injuries, leaving only serious injuries of the extremities as indication for their use. Last but not least a proper psychological approach of the victim is of paramount importance

MEDICAL TEAMS
purpose, structure and function

PURPOSE

Complicated accidents;

Specific accidents or disasters,
(chemical, nuclear, fires and ferries);

Man-made disasters;

Naturally-occuring disasters

STRUCTURE

A-team: physician and/or nurse;

B-, C-, N- and H-team: medical specialists, specialized nurse and specialized technician;

D-team: two specialists (e.g. surgeon and anaesthesiologist) and two specialized nurses;

I-team: various medical specialists, physicians, nurses and auxiliaries.

A well functioning disaster organization affords the wounded a greater chance of survival. The availability of medical teams adds to the efficiency of such an organization. Experience gained in recent wars, in which the mortality rate among wounded fell markedly with the establishment of such field teams, bears this out.

Actual and imaginary situations in which such a team can be vital:

1. - Train disasters and multiple crashes generally involve trapped victims. Such casualties require optimal support since their extraction from the wreckage with the equipment available may take considerable time.
   - Disasters occuring on difficult terrain with consequent delay of the rescue operations.
   - Certain weather conditions such as ice and snow can delay considerably the recovery and transport by ambulances of casualties.
   - Widespread calamity - large numbers of casualties spread over a large area may cause an immediate shortage of ambulances necessitating drawing on the reserves of more distant regions, with further delays as a consequence.
   - Anticipated disasters, such as hijackings and the holding hostage of large numbers of persons (D-team).

Apart altogether from the above mentioned indications, a team may also be in a position to lend invaluable assistence in the following circumstances:

2. - When the situation at the disaster site is adequately catered for, this disaster team might well be directed to the nearest hospital in order to step up the so called "treatment capacity". Experience from recent wars and disasters indicated that the mortality among the injured increases by 1-3% per hour of delay in instituting surgical intervention. In order to reduce the surgical time lag the team should form a complete operating team in that hospital with a view to increasing capacity; after all, the capacity for mechanical injuries is dependant on the the surgical, anaesthetic, medical and nursing personel available (D-team).
3. - Such teams should exist also for availability in emergencies of an international nature, provided these teams could reach the disaster spot within a reasonable time (I-teams).
4. - On the other hand, accidents or so called single event situations necessitate also the availability of teams. Such complicated accidents, where casualties are trapped, e.q. in a carwreck, building trend or elevatorshaft, require a doctor and/or nurse only (A-team).

FUNCTION

alerting procedure

directly:	from accident/disaster site to team or
indirectly:	via any central or regional office
phased:	in one or preferably two steps

material support

carried by the team itself
or
obtained by a rendez-vous system

transportation

private car (with police escort)

fire engine

police car - for local deployment

ambulance

helicopter for regional deployment

plane for international deployment

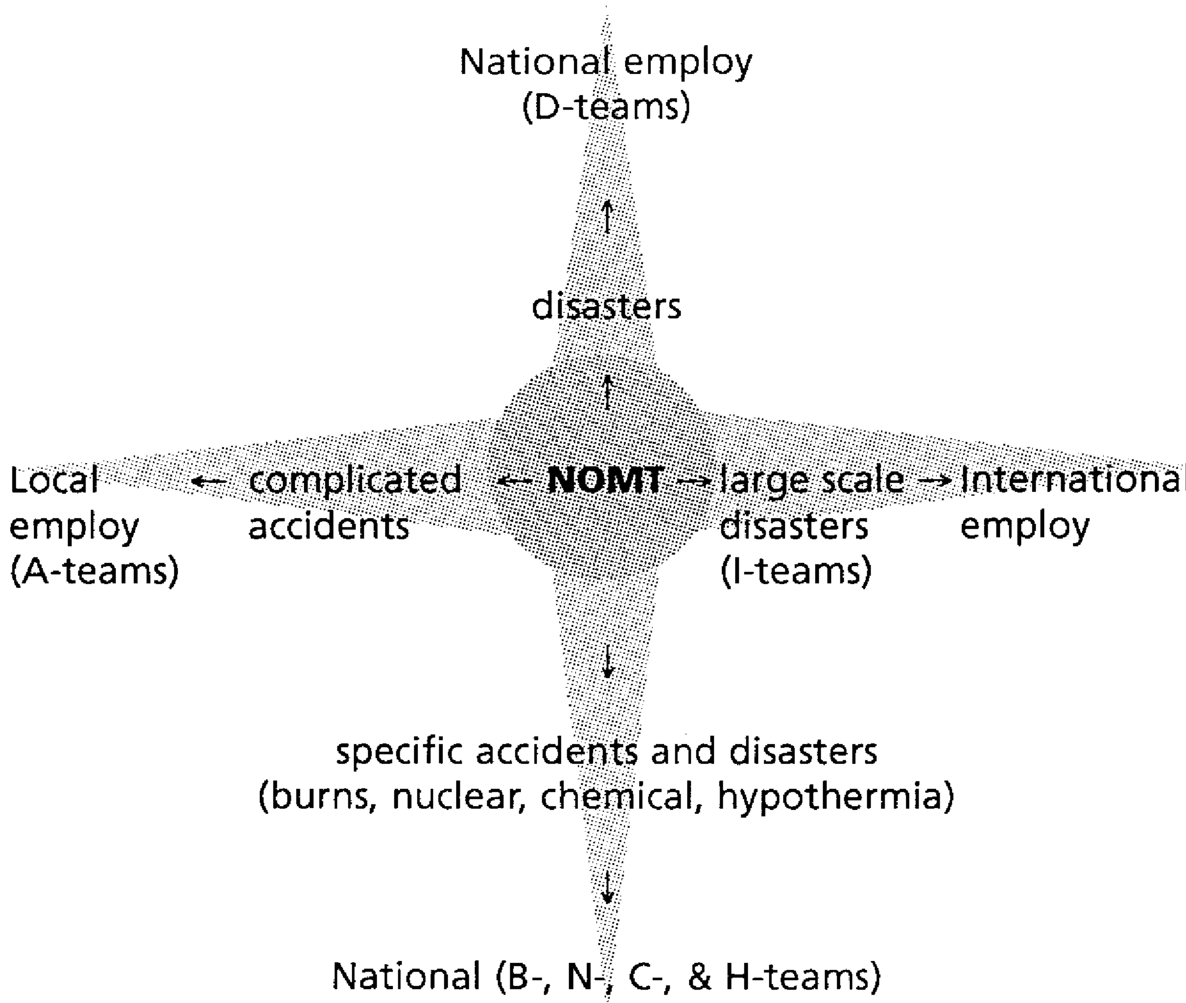
5. - For specific disasters, e.g. chemical and nuclear, specialized teams could be employed. The same holds for disasters with many burned patients or hypothermic casualties. These so called C-, N-, B- and H-teams are of a more advisory nature as compared to the other teams.
6. - Especially in the case of greater calamities such field teams are in a position to furnish expert and detailed information regarding the wounded and the nature of their injuries to surrounding hospitals and other instances concerned with the welfare of casualties.
7. - Moreover, a disaster always presents the opportunity for further criticism of the existing organization and its technical resources, as well as affording to the chance to conduct research into aspects of disaster medicine.

The composition of medical teams varies with its purpose: complicated accidents require a doctor and/or nurse only (A-teams), naturally-occurring disasters require larger teams (I-teams), including doctors, specialists and nurses, while specific disaster necessitate the utilization of specialists and specialized nurses.
As far as the composition of disaster teams is concerned, the aim should be that of an operation-room team comprising as a minimum a surgeon or experienced surgical resident, an anaesthesiologist or experienced resident, a trained theatre sister, and an experienced casualty sister. It should be possible to implement this permanent surgical/anaesthetic establishment with, for example, internal physicians, chest physicians and psychiatrists. It is important that such a four or five man team should be able to travel in one car or any other vehicle.
Ideally, the provision of such teams would be the responsibility of clinics entrusted with specialist training, each of these clinics participating in a duty roster. The only obligation would be that of quaranteeing the availability of a field team at the time indicated of the roster. For this purpose, the country should be divided into a number of regions, each with its own academic unit. This infers that one hospital in each region is on call at the time stipulated on a previously agreed duty list. Obviously, the greater the number of teams at disposal, the less frequent the necessity to be on call.

From an organizational point of view the simplest way to form a team is to enlist the duty surgeon or surgical resident, the duty anaesthesiologist or resident, and the duty theatre and casualty sister. Most hospitals with a teaching commitment also have a second-on-call roster. In the event of the team being called out their duties can be assumed by the reserves.

SUMMARY

NATIONAL ORGANIZATION OF MEDICAL TEAMS



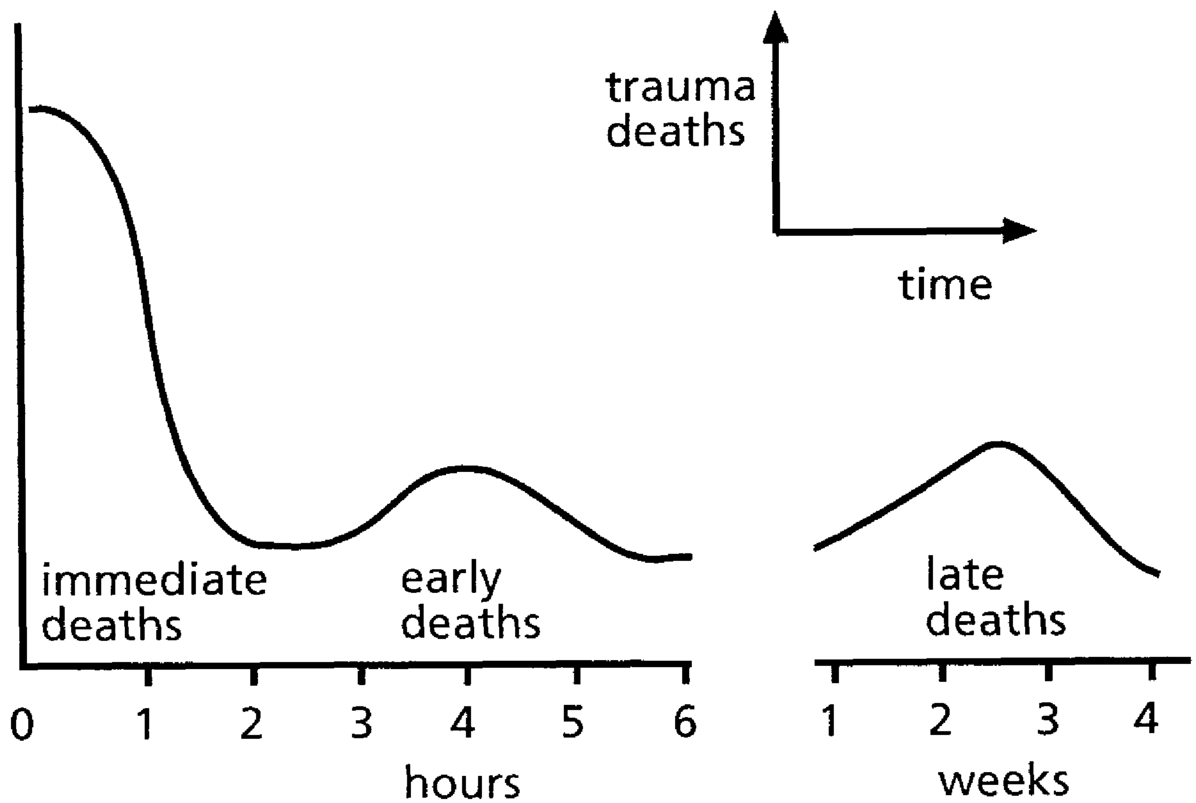
It is desirable that the hospital be alerted from a central office. This central office is also responsible for drawing up the duty rosters. The process of raising the alarm should be phased in order to obviate the unnecessary calling out of personnel who are not needed.
On receipt of the alarm the team is mobilized and preferably sets out in a private car under police escort. Helicopter transport is less attractive than it at first might appear: firstly, because few hospitals can boast of a heliport, and secondly, since the 24 hours standby of a helicopter is difficult to realize.

On arrival at the disaster or accident area priority assistance is offered to triage I casualties with respiratory and/or circulatory problems. Of course, the support of trapped victims also begins right away.
Apparatus and equipment, together with their transport to the site, are the responsibility of the central office mentioned. The need for withdrawal of resources from surrounding hospitals is thus obviated.
Emergency surgery on the site or at a nearby hospital calls for the instrumentation, drugs, disinfectants, bandages, anaesthetic apparatus and accessories, linen, emergency lighting, stretchers, and a host of other provisions according to a previously drawn up list. Additionally, it is recommended that one or more ambulances be designated and equipped as a first-aid post on the (disaster) site. Together with the above mobile equipment, these ambulances make up an ideal hospital unit.

The leader of the team, in addition to his funtion as a member, is charged with relaying information to the surrounding hospitals and supervising the conduct of casualties and helpers alike.
When the disaster or accident area has been cleared, the team could withdraw to any neighbouring hospital requiring assistence. In any case, it is desirable that a team which has been working for 12 hours should be relieved by a second group. Such a succeeding team might well come from a different region.
Finally, it is desirable that the proper agencies clarify the legal position of members of such a team, whether medical of nursing.

TRIAGE AND THE 1- AND 6- HOURS PERIOD FOLLOWING A DISASTER*

* ADAPTED FROM AN ARTICLE IN THE DUTCH TIJDSCHRIFT VOOR TRAUMATOLOGIE (1995)



Trimodal distribution of deaths
as a result of mechanical injuries

It is unknown whether or not deaths from other causes of injuries follow this pattern.

From the well known curve of Trunkey, the trimodel distribution of trauma-deaths, related to time, it appeared that the first peak represents people who die soon after injury. This "immediate deaths" group, amounting to 50 % of all traumadeaths, is caused by lacerations of the brain, the brain stem, the spinal cord, the heart or one of the major vessels.
Virtually none of these patients could be saved, even under the most favourable medical conditions.
The second peak, characterized as "early deaths", represents people who die within the first few hours after injury, usually due to major internal hemorrhages in one of the bodies' cavities, head, thoracic and abdominal cavity. Almost all injuries of this type are considered treatable by currently available medical procedures applied within one hour, the "golden hour", following injury.
These procedures should preferably be initiated at the accident site already and comprise basic and advanced (trauma) life support.
The third peak of so called "late deaths" corresponds to victims who die days or weeks after sustaining injury, usually due to multiple organ failure or infection caused by insufficient medical treatment. The second and third peak of trauma deaths - comprising around 50% of all deaths - could thus be prevented by proper prehospital and hospital treatment as soon as possible. The trimodal curve of Trunky is based on almost 2000 deaths caused by mechanical traumata. Whether deaths caused by chemical or thermal traumata follow the same curve is unknown.

Type of injury	mechanical/thermal
	chemical
	nuclear
	biological

The majority of disaster *types* leads to mechanical injuries, who may require surgical intervention.

Type of injury

In this respect injuries can be of various origin:

mechanical	leading to wounds, fractures, dislocations, hemorrhages (internal and external), lacerations, concussions and organ damages.
thermal	high temperatures: burns in various grades, varying from simple hyperaemia to complete charring; low temperatures: leading to hypothermia, starting with mild through moderate and finally deep hypothermia (≤30°C);
chemical	resulting in simple irritations of mucous membranes (nose, eyes, mouth and throat) to systemic effects in various organs; like lungs and central nervous system;
nuclear	causing radiation injuries, either external, resembling burns, or internal by inhalation or ingestion of radioactive material with immediate, prolonged or late systemic effects;
biological	either by infectious diseases, caused by pathogen micro-organisms, or by malnutrition as a result of deficient alimentations.

Triage
mechanical, thermal and chemical injuries

T1 ABC unstable victims due to obstruction of airway (A) or disturbance of breathing (B) or circulation (C). Immediate life support and urgent hospital admission.

T2 ABC stable victims to be treated within 4-6 hours, otherwise they will become unstable. First-aid measures and hospital admission.

T3 ABC stable victims with minor injuries not threatened by instability. Can be treated by general practitioners.

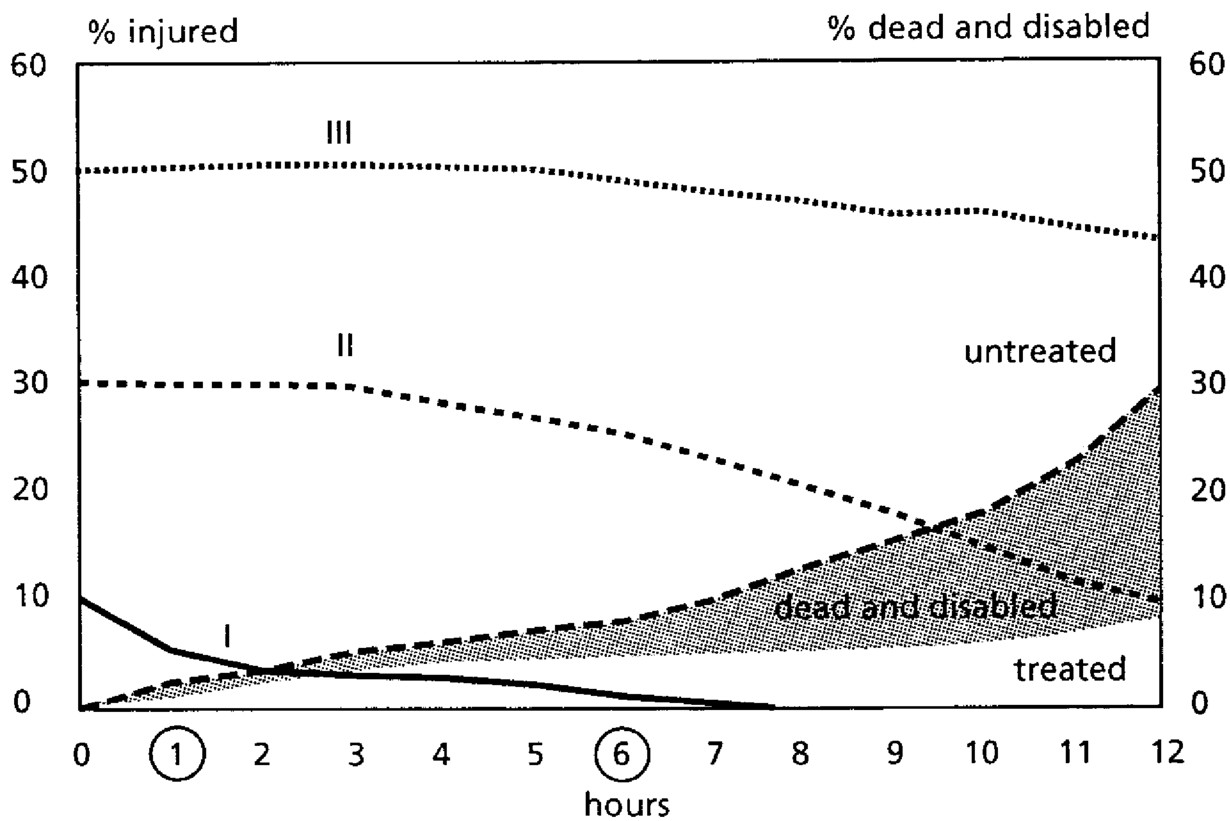
T4 ABC unstable victims who cannot be treated under the circumstances given.
This classification should be performed by experienced medical personnel!

TRIAGE

During the Napoleontic wars warsurgery was introduced and the sorting of casualties became common practice. In French "trier" means sorting and triage therefore stands for sorting-out or the classification of, in this case, the wounded.
As a general rule the treatment of casualties in disaster situations had to be carried out under conditions of scarcity - scarcity of manpower, materials and time. Therefore, optimal use of all available resources is essential.
In assessing individuals for appropriate classification, the nature, extent and severity of the injury, the urgency of treatment, and the existence of co-existing lesions should all be taken into consideration. In any case classification should meet the following requirements:
a. it should be to the benefit of the victim,
b. it should fit into the existing disaster organization.

As described in the chapter "an introduction to disaster medicine", triage can be defined as the classification or sorting of victims according to the injuries sustained. As can be seen from the above list the sorting of victims in a mass casualty situation should be ideal when one uniform methodology could be utilised, which however is not (yet) available.
So far, only for so called mechanical, thermal and chemical lesions a uniform methodology has been introduced, which is based on the condition of the vital functions, ventilation and circulation. These functions are in fact the representatives of the state of body health. When disturbances of vital functions feature this state of body health following a mechanical, thermal or chemical injury, the prognosis is poor. An example of an uniform and standardazid triage system for victims with mechanical, thermal and chemical lesions, which was introduced in 1987 in The Netherlands, is shown.
In view of the fact that the condition of a given patient is subject to alteration or deterioration it is of the utmost importance that classification of the injured be subjected to continuous reassessment. The danger lies in the fact that a score, once determined, is not subjected to reappraisal.
The uniform character of the triage described renders possible classification according to a number of factors including the urgency of treatment, transportability and prognosis, bearing always in mind that reassessment is essential, especially when the delay time is prolonged.

Injuries and Time



Relations between time and number of injured or dead (and disabled) in %

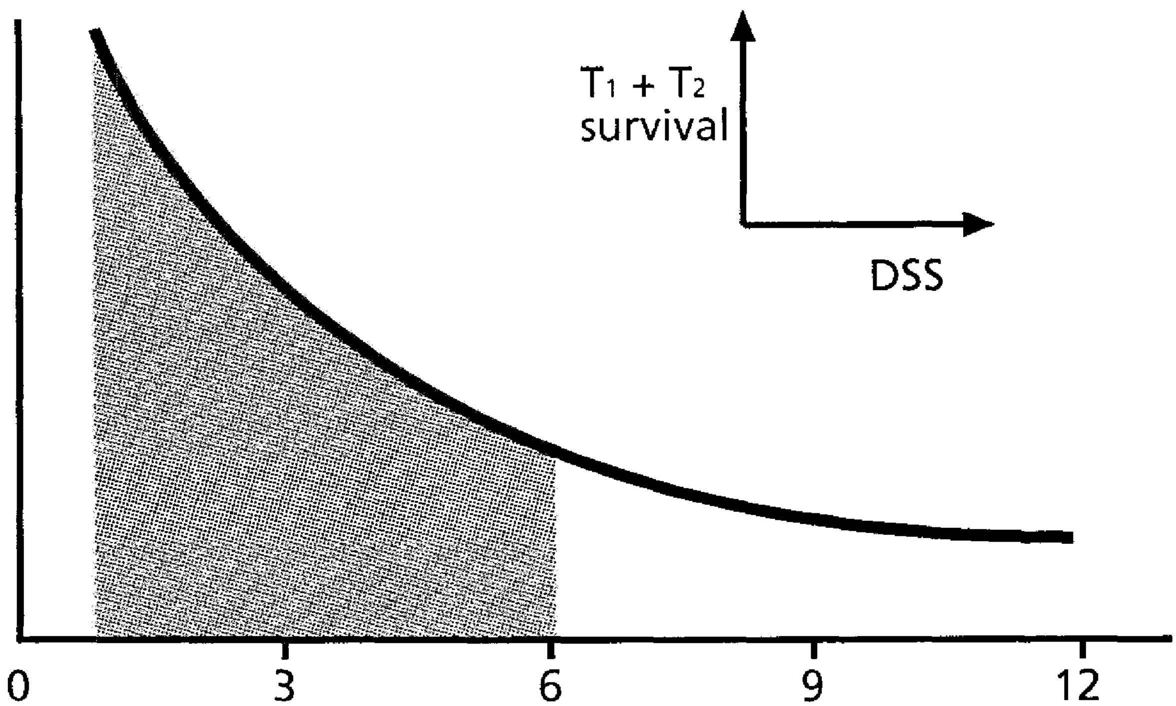
TRIAGE, THE GOLDEN HOUR AND FRIEDRICH'S TIME

Those victims showing disturbances of vital funtions, usually expressed as A (airway), B (breathing) and C (circulation) instability, are classified or sorted as priority 1 or triage 1 (T1) patients. Within this T1 group there is a certain variation possible and therefore this group can be subdivided - if some time is available - into subgroups with the aid of the so called revised trauma score (RTS). The subgroup with the least chances of survival, under the given circumstances, should be addressed as T4. Unless certain life-saving measures could be installed within the shortest possible time, mortality, morbidity an disability is increased considerably in this group. This period should not exceed 1 hour and is therefore called the "golden hour", a well-known concept in traumatology and emergency medicine.

A substantial number of victims is moderately injured; in other words those patients who could develop disturbances of vital functions or could develop infections. Untreated fractures or organ damages are continuously seeping blood, while open wounds can be contaminated with microorganisms.

These victims may therefore develop a state of shock (=disturbance of circulation) and insufficient breathing (= disturbance of ventilation). From surgical experience this group of mechanically wounded victims should preferably be treated within 4-6 hours after injury. This so called "Friedrich's time" should not be exceeded, otherwise, as mentioned, disturbances of vital functions may develop resulting in a considerable increase of mortality, morbidity and disability. This group of initially, moderately injured victims may become ABC instable within 4-6 hours and are classified as T2.

Another substantial number of victims is only slightly injured and even under the most unfavourable circumstances they will not develop disturbances of vital functions. This group is classified as T3. Therefore, in a so called " mass casualty situation", victims of mechanical, thermal or chemical violence can be classified or sorted, apart from the deaths, as T1, T2, T3 and T4 and should be treated accordingly.



The higher a disaster on the Disaster Severity Scale (DSS) the less $T_1 + T_2$ survivals!

This implicates a different medico-organizational approach of disasters scaled, say 6 and lower as compared to disasters scaled 6 and higher.

In a mass casualty situation the least mortality, morbidity and disability can be obtained by providing the T1 victims basic and advanced (trauma) life support within 1 hour and the T2 victims those first-aid measures within 4-6 hours so that worsening of their condition can be prevented. Cumulative calculations show a considerable increase in mortality, morbidity and disability of up to 30%, if T1 and T2 victims are untreated for 12 hours. When T1 victims are stabilized within 1 hour and T2 victims receive adequate first-aid measures within 4-6 hours, mortality, morbidity an disability can be kept as low as 5%-10%.

Also the T3 victims should receive medical attention, however profit can be achieved only in morbidity and disability and not in mortality. It is thus clear that (medical) rescue should focus its attention, in the first hour after a disaster has occurred, to T1 victims and in the following hours to T2 victims and meanwhile directing T3 victims towards medical provisions further away. This, of course, holds for the smaller type of disasters, say DSS ≤6, however, disasters of a higher magnitude will show a different pattern. In a disaster situation when the stricken area is large and/or the rescue procedures will be timeconsuming, the golden hour and Friedrich's time will be exceeded by many hours, resulting in a high mortality as mentioned before. Meanwhile, however a number of T2 victims has become T1 and will die ultimately, until only the T3 group will remain and perhaps some borderline T2/T3 victims. It is unknown, however, how long it will take until the total T1 and T2 group will be extinguished completely. Among others, this will be determined by the type of injury, average age, underlying diseases and external circumstances, like temperature.

RUTHERFORD'S RULE*

and estimating numbers of disaster victims

* ADAPTED FROM AN ARTICLE IN ISDM-PROCEEDINGS (1995)

A reliable estimation of the number of casualties is of paramount importance in disaster management!

Rutherford's Rule

disaster	Man-made →	overestimated	number of casualties
	God-made →	underestimated	

It was William Rutherford, a surgeon from Belfast, who pointed out his experience that in man-made disasters the numbers of casualties were always exaggerated, while naturally occurring disasters usually provided figures, which were initially too low. In a series of disaster in 1994 and 1995 this observation was confirmed.
In honour to this true pionier in disaster medicine this general experience should be named after him. Thus, according to Rutherford's rule, the number of victims of so-called man-made disasters is always overestimated, while numbers are underestimated in God-made disasters. Recent examples are the cargo plane crash in the Bijlmermeer, at the outskirts of Amsterdam, and the earthquake at Kobe in Japan, respectively. Exceptions to this rule are cases in which there is a known number of victims, such as in ferryboat disasters and passenger plane crashes.
Estimating the number of disaster victims is never an easy task, however a more accurate approach to this issue is an essential part of contingency planning, for the following reasons:

- an underestimation of numbers could result in too little emergency aid, which policymakers would certainly not wish to have on their conscience;
- an overestimation, however, means an unnecessary deployment of people and material;
- too many aid workers obstruct operations on the site itself, not only by their physical presence but also by the surplus of material they have with them;
- although it cannot be proven, it may be said that the presence of too many aidworkers is as detrimental as too few.

Aside from these arguments, which are related to repressive contingency planning, in the preparatory stage an accurate estimation of the number of victims is clearly going to be advantageous, as it allows for structural preparation and drills facilitating full utilization of the entire chain of medical care, and guaranteeing continuous transportation of the injured - from rescue at the disaster area itself to the hospital bed.

ESTIMATING NUMBERS OF DISASTER VICTIMS

Basic figures for contingency planning

IMMOVABLES			RANGE[1]
Residential area[2]	Per hectare	Low-Rise Buildings High-Rise Buildings	20-50 50-200
Business area	Per hectare		0-800
Industrial area	Per hectare		0-200
Leisure area	Per type	Stadium Discotheque Camping-site	-[7] - -
Shops	Per type	Department store Arcade	-[7] -

MOBILE OBJECTS			RANGE[1]
Road transport	Per 100 M (length)[3a] Per type[3b]	Multiple collision Coach	5-50 10-100
Rail transport[4]	Per type	Single deck Double deck	5-400 10-800
Air transport[5]	Per type	Small Large	10-30 150-500
Inland Shipping[6]	Per type	Ferry Cruise ship	10-1000 200-300

1 depends on date, time and other local circumstances.
2 combination of number of residents per house (1.8-2.8) and number of houses per hectare (30-70)
3a per car: lenght 5m and 1.5-3 passengers (see 1).
3b (articulated) local bus or (articulated) double-deckerbus.
4 carriages of 3 or 4 wagons (see also 1)
5 seat occupancy 70%.
6 seat occupancy 80%.
7 awaiting further research.

The importance of creating order in chaos, i.e. a disaster, is gaining increasing recognition. Mathematical models of disasters not only provide methods of gaining further insight into the processes inherent to disasters, but also provides instruments with which to control these processes. One of the necessary parameters is a general estimation of the numbers of victims and, in particular, the number of injured for hospitalization. The word 'injured' has been chosen to include victims of chemical,nuclear or biological disasters and not only mechanical disasters.

A more accurate estimation of numbers of victims constitutes the basis of calculations toward establishing the capacity of the entire chain of medical care. Capacity is determined by the quality of the aid workers, their material and methods, while they, in turn, are dependent on the nature of the injuries, as mentioned above: usually unknown variables, awaiting a great deal of research.
The table attempts to show as accurately as possible the number of victims using various base figures of minimum and maximum numbers. The following examples serve to illustrate this table. Of course, the figures in the table vary from country to country and perhaps also even from region to region; however, this table may serve as an example of how to produce these data.

Each country, region, city or district may produce tables of occupancy for mobile and immobile objects. Based on Rutherfords' Rule these tables can provide more accurate estimates of the number of victims (N).

This is of paramount importance,
not only in the repressive,
but also in the preparedness phase of disaster!

Example 1*

Take a multiple collision of 150 metres long at peak hour on a national trunk road. In this example, the maximum number of victims, both dead and injured is 90, that is 150 metres divided by the length of a car (5 meters), multiplied by the number of lanes, multiplied by 1.5, the average seat occupancy per car during peak hours.

It may be assumed that of these ninety people, 5-10 will be dead and that there will be 30-35 seriously (10%) and moderately (20%) wounded, who need to be hospitalized. The 40-60 other people involved will be either slightly wounded or not wounded at all. Supposing that those slightly wounded do not need ambulance transportation we may assume that 15-20 ambulances are required for hospitalization of those more seriously wounded within a clearance time of one hour.

Example 2*

Take the derailment of a double-decker train -3 carriages- on Sunday morning. Since the Dutch Railways refuse to publish seat occupancy figures we can only make a rough estimate of a few dozen victims. Probably half of those need to be hospitalized by means of 6-9 ambulances within a clearance time of one hour.

Example 3*

Take a plane crash on a block of flats in the Amsterdam Bijlmermeer on Sunday evening. It soon becomes apparent that the plane involved is a cargo plane and that 40 apartments have been destroyed. According to the table, apartments in the Netherlands are occupied by an average of 2.2 people, which, in this particular disaster, would mean a total number of 88 victims. The majority of these victims, say 80%, will be fatally injured due to the gigantic impact of the crash, as well as the fire. The expected number of wounded is 20 and these will be either seriously or moderately wounded and need to be hospitalized. Since the victims will be difficult to extricate the clearance time will be 4 hours at least, which means that no more than a few ambulances are required. (However, 72 ambulances actually turned up!)

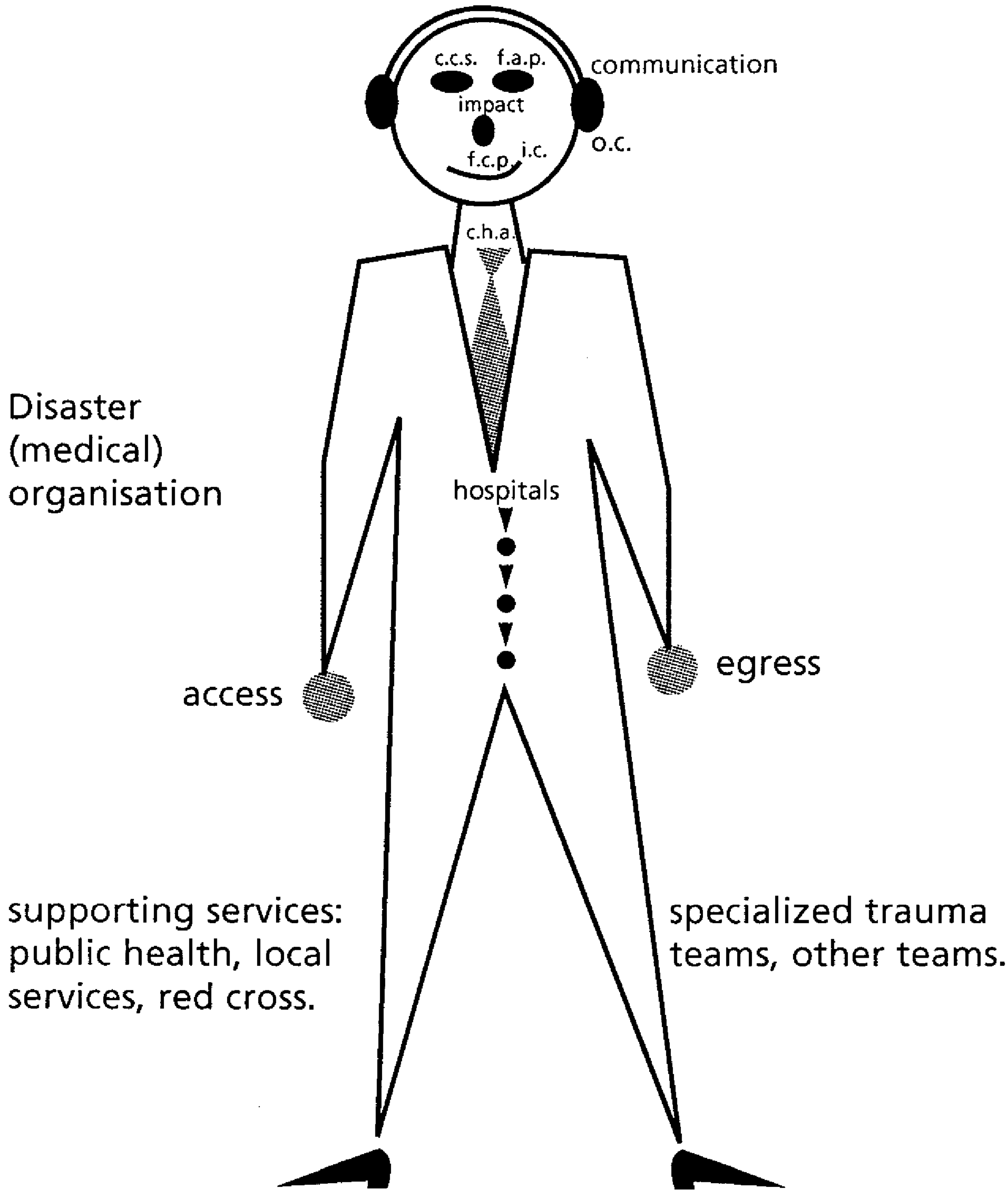
* For calculations see appropriate chapters.

THE CHAIN OF MEDICAL CARE*

and its capacities

* ADAPTED FROM AN ARTICLE IN THE DUTCH TIJDSCHRIFT SPOEDEISENDE EN RAMPENGENEESKUNDE (1994)

f.c.p. = forward control point
i.c.. = inner cordon
o.c. = outer cordon
c.h.a. = central holding area for ambulances
c.c.s. = casualty clearing station for T1 and T2 victims
f.a.p. = first-aid post for T3 victims



The aid chain of medical care refers to the medical and nursing care of casualties at every stage from the scene of the disaster to their admission to hospital. The chain has two sub-chains: one for the deceased, which is of relevance for the Victim Identification Team, and one for ambulatory patients not requiring hospital treatment, who should be referred to GPs.

Organisationally, this chain of medical care can be divided into three more or less self-contained links:

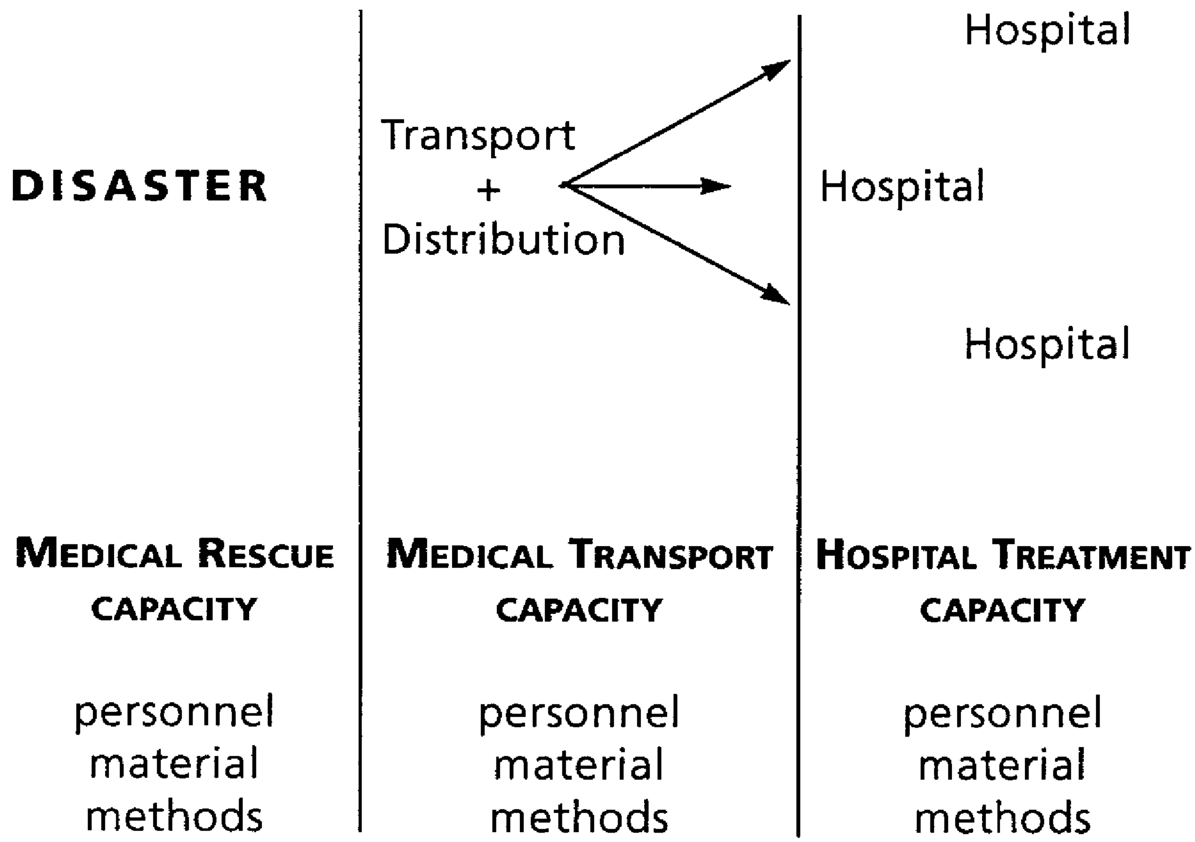
1) Medical organisation at the scene of the disaster;
2) Transport and distribution of casualties to the various hospitals;
3) Organisational procedures in hospital.

Re 1

The scene of the disaster and the immediate surrounding area is characterised by an impact area, i.e. the place where the actual disaster occurred, a filter area, through which organised and non-organised aid is channelled, and beyond this, an organised community aid area where the provision of primary aid is organised.

The police should close the impact area by means of an inner cordon. At the edge of the impact area the first ambulances to arrive should establish a forward control point to function as a first command, communication and coordination point. At suitable points nearby the impact a casualty clearing station for T1 and T2 victims and a first-aid post for T3 victims should be established. Around these an outer cordon should be laid. At the edge of this outer cordon a central holding area for ambulances is positioned. The area in between the two cordons is than the filter area as mentioned. In the organized community aid area, outside the outer cordon, the hospitals are situated and access and egress to and from the disaster area take place.

As a rule, primary aid is provided by local services such as the police, fire brigade, public health including, ambulance service, doctors and nurses (working either as individuals or in teams) and, usually at a later stage, the Red Cross or any other specialized service. If the disaster extends beyond the municipal boundary, the regional services will lend assistance. If it extends beyond the regional boundary, the point at which provincial and then national services are called in is very soon reached.


Hospital
DISASTER
Transport
+
Distribution
Hospital
Hospital
MEDICAL RESCUE CAPACITY
personnel
material
methods
MEDICAL TRANSPORT CAPACITY
personnel
material
methods
HOSPITAL TREATMENT CAPACITY
personnel
material
methods

It will be clear that, from the organisational viewpoint, things must run smoothly to enable all the medical and non-medical activities in the disaster area to be carried out in an orderly fashion. Every public health service or specialized other services responsible for providing medical assistance in such a situation must have a disaster relief plan.

Re 2
The transportation and distribution of casualties to the various hospitals, which will usually be located in the surrounding area, is the second self-contained link in the chain. In the event of emergencies, these tasks are the responsibility of the Central Ambulance Post (CAP). In a disaster a CAP will put two plans into operation: one for allocating casualties to the various hospitals according to their treatment capacity (the casualty allocation plan) and one for obtaining assistance from other ambulance posts nearby (the ambulance assistance plan).

When disasters occur, the Red Cross or any other organisation also has a role to play by providing its own vehicles for transporting casualties. These are usually somewhat more basic than the CAP ambulances.

Re 3
Organisational arrangements in hospitals are a complex business. Broadly speaking, each specialism has its own procedures. The daily "supply" of patients gives the overall picture. Admissions may reach peak levels at certain times but these peaks are never as extreme as in a disaster situation. When a disaster occurs, the arrival of large numbers of casualties will disrupt normal organisational procedures to the extent that chaos will result unless a contingency plan can immediately be put into effect. A plan of this kind is characterised by an alert and preparation phase. If it is properly implemented and exercised, large numbers of casualties can be handled in ten to twenty minutes.

MRC depends on

- Types of injury
  - mechanical
  - chemical
  - nuclear
  - biological
- $S = \frac{T_1 + T_2}{T_3}$
- Number of doctors, nurses and paramedics and their education and training
- Essential supplies

MTC depends on

- Number of ambulances
- Clearance time
- Accomodation per ambulance
- Distance & speed

HTC depends on

- Types of injury (see MRC)
- Number of essential specialists and nurses and their training in disaster procedures
- Utilities and supplies.

THE CAPACITIES IN THE CHAIN OF MEDICAL CARE

Medical rescue capacity (MRC)

Since the T1+ T2 / T3 ratio is known for the various types of disasters resulting in various types of injuries, the MRC can be estimated (see chapter on Evaluation of disasters).
Also, the MRC with and without education and training of personnel is known; the same holds for doctors and nurses alone or as teams.
As a result of this, the demand of supplies is also known!

For futher reading see the next chapter.

Medical transport capacity (MTC)

In a mass casualty situation the number of ambulances needed (X) is directly proportional to the number of victims to be transported (N) and to the transport time (t) and inversely proportional to the number of victims per ambulance (n) and to the required clearing-time of the disaster site (T).

For further reading see one of the next chapters.

Hospital treatment capacity (HTC)

Hospital treatment capacity refers to the number of victims that can be treated in a hospital within a given period of time, e.g. one hour. If the casualties have mechanical or burn injuries, HTC is determined by the number of surgeons, anaesthesiologists and specialist nurses and by the operating theatre and intensive care facilities available. These variables are as a rule related to the number of beds in the hospital. Research of both a theoretical (see table) and an empirical approach has shown HTC to be about 2-3%, i.e.2-3 casualties per 100 beds per hour. Thus a medium-sized district hospital containing a minimum of 300 beds could treat about 6-9 casualties an hour. Taking account of fatigue on the part of the staff and the fact that the hospital would run short of supplies, its total capacity for a period of 8-10 hours would be about 50-70 victims.

$$MRC \approx MTC \approx HTC$$

The lowest capacity in the chain will determine the capacity of the whole chain!

	MECHANICAL	CHEMICAL	NUCLEAR	BIOLOGICAL
MRC	+	-	-	-
MTC	+	±	±	±
HTC	+	-	-	-

As can be seen in this summarising table only the capacity for casualties with mechanical lesions (incl. burns) are known so far.

The three separate parts of the chain of medical care must be about the same in terms of capacity, i.e. MRC ≈ MTC ≈ HTC, otherwise the capacity of the entire chain will be determined by the lowest common denominator. For example, there is absolutely no point in expanding MTC by means of additional ambulances if the HTC of the surrounding hospitals remains the same. This will inevitably cause chaos in the delivery of casualties to hospital.

So far, the discussion was based on casualties with mechanical lesions, including burns.
In case of chemical, nuclear and biological lesions the capacties are unknown!!
This should be a stimulus for futher research.

Application of the above principles to a municipality, province or indeed the whole country makes it possible to make a rough estimate of disaster preparedness for mechanical lesions. For a detailed description and a precise calculation reference should be made to one of the next chapters.

ESTIMATION OF THE NUMBER OF MEDICAL PERSONNEL NEEDED AT THE DISASTER SITE

By Medical Rescue Capacity (MRC) is meant the number of casualties per hour that can be adequately and efficiently offered lifesaving and limbsaving help at the disaster site. This number will depend on the following factors:

- In each phase of the chain of medical care the capacity is determined by PERSONNEL, by MATERIALS and by METHODS;
- In this case the personnel are doctors, nurses and first-aid providers. The extent of their training and experience in disaster medicine will largely determine their efficiency and thus the MRC. The MRC will also be determined by whether or not work is carried out on a (fixed) team basis;
- the MATERIALS required to carry out the lifesaving and limbsaving activities also determine the MRC, both qualitatively and quantitatively;
- the lifesaving and limbsaving actions constitute the principal METHODS at the disaster site. Doctors, nurses and first-aid providers must also learn how to carry out other duties at the disaster site, such as communication and registration;
- the MRC is further dependent on the type of injury concerned: mechanical, chemical, nuclear, biological, or combinations thereof. It should be noted, however, that whatever type of injury is involved, the lifesaving and limbsaving actions are (virtually) the same;
- finally, the MRC is determined by the severity factor (S). This factor represents the ratio between the number of injured who need to be admitted to hospital (T1 and T2) and the number of casualties who need not be hospitalized (T3).

  It is in particular the T1 and T2 casualties at the disaster site who determine the medical consumption, and to a lesser degree the T3 casualties. In short, the higher the S, the more T1 and T2 casualties there are compared to T3 casualties and the more MRC is needed.

Until recently the MRC for mechanical injuries could only be approximated on the basis of impressions gained during exercises. These have assumed that 12 (T1 + T2) casualties would be hospitalized per emergency team per hour.
A mobile medical team in the Netherlands comprises a surgeon, an anaesthesiologist and two specialized nurses. Because these emergency teams have considerable clinical experience but limited on-the-ground experience, four ambulance nurses - with less clinical experience but more on-the- ground emergency experience - might provide the same capacity.

MEDICAL, NURSING AND FIRST-AID TASKS AT THE DISASTER SITE

The medical actions to be carried out at the disaster site, as derived from the legal requirements, have been defined as followed:
- the three-fold airway manoeuvre; *
- mouth-to-mouth or mouth-to-nose resuscitation;
- external heart massage;
- application of stable side position; *
- oropharyngeal aspiration *
- oropharyngeal intubation; *
- orotracheal/endotracheal intubation; *
- balloon respiration; *
- oxygen administration; *
- chest tube placement; *
- pericardial puncture; *
- insertion of an intravenous cannula for infusion; *
- hemorrhage control; *
- insertion of a gastric tube; *
- immobilization of fractures; *
- insertion of a bladder catheter; *

In the absence of emergency team specialists, the following tasks are optional (though hardly ever indicated at disasters):
- coniotomy;
- mouth to mouth (nose) resuscitation;
- bladder puncture;
- external heart massage;
- insertion of a sternal screw;
- carrying out a phlebotomy.

The first-aid providers tasks at the disaster site are the following:
- unloading casualties;
- supervision of casualties upon their arrival at the casualty collection point;
- assistance with treatment;
- arranging internal transport;
- guarding casualties;
- presence at the loading of casualties;
- care for casualties during treatment;
- activities at the morgue;
- materials management.

Until now this number of casualties, 12, has been adopted for an emergency team, but is it realistic? Further analysis provides the following insights. Lifesaving and limbsaving activities might be further subdivided into a series of separate actions, such as infusion and intubation. By drawing up an inventory of these actions and assigning them an average duration, the MRC could be calculated for all kinds of T1/T2 ratios, taking into account which duties a first-aid provider, a nurse and a doctor can and is authorized to carry out. See table on medical, nursing and first-aid tasks.
To which actions can an average duration be assigned? These actions are presented in the same table and are indicated with an asterisk (*). In a separate table the average durations are added. These times were obtained partly from the literature and partly through our own research.

The T1/T2 ratio may vary from 1 : 2 to 1 : 4. For one T1 casualty and three T2 casualties, for instance, an experienced team consisting of a doctor/specialist and a nurse supplemented by one or two first-aid providers as the necessary support staff, would need (8 + 15) + (3 x 13) = 23 + 39 = 63 minutes. This means four (T1 + T2) casualties per hour. A mobile medical team, which comprises two such teams, (see above) would therefore be able to 'process' eight (T1 + T2) casualties. This is considerably fewer than had been originally estimated.

Assuming the fire brigade's rescue capacity (RC) to be 24 (T1 + T2 + T3) casualties (a value which requires verification), this means 8 (T1 + T2) casualties and 16 T3 casualties in the event of an S of 0.5.
The 8 (T1 + T2) casualties would therefore require one mobile medical team supplemented by four first-aid providers. A few ambulance crews and the remainder of the first-aiders would then be available for the 16 T3 casualties. The Medical Rescue Capacity would therefore be able to cope with an S of 0.5. In the event of an S of 2.0, however, two mobile medical teams would be needed.

The nurse's tasks at the disaster site are the following:

1 *Assisting the doctor*

The nurse assists the doctor in carrying out the necessary medical treatment. A nurse should be able to carry out the following medical and technical actions independently:

- three-fold airway manoeuvre;
- arranging stable side position;
- oropharyngeal aspiration;
- oropharyngeal intubation;
- mouth-to-mouth/mouth-to-nose resuscitation;
- external heart massage;
- oxygen administration;
- hemorrhage control;
- immobilization of fractures by means of splints;
- insertion of a gastric tube.

These actions all form part of the certified A-nurse training course. In emergency situations the nurse will also have to carry out certain medical actions independently, even if the conditions of 'assistance only' are not met; the legal obligation to assist those who need help (to which the nurse, as any citizen, is subject) forces him/her to do so. The nurse will nevertheless have to restrict himself/herself to those tasks for which he/she has acquired the necessary theoretical and practical skills. The nurse may only carry out elaborate medical actions if:

- he/she has completed a theoretical and practical training course for this purpose;
- communication with a competent doctor is possible at a certain stage in the care provision process;
- these actions are laid down in a protocol.

2 *Nursing care provision*

An essential condition for optimal care provision is efficient cooperation between the doctor and nurse.

3 *Safeguarding hygiene*

Although hygienic conditions are difficult or impossible to safeguard completely at the casualty collection point, hygiene must nevertheless be as good as possible in the circumstances.

4 Control and supervision of first-aid providers actions

MEDICAL ACTS AND AVERAGE LENGTH OF TIME FOR DOCTORS AND NURSES WORKING AS A TEAM AT THE DISASTER SITE

T1 Disturbances of vital functions, breathing and circulation

. orientation & positioning	1	*
. airway management	1	
. orophargyngeal intubation	1	minimal 8'
. oxygen administration	1	
. intravenous line	3	
. stable side position	1	
. hemorrhage control	3	
. fracture immobilization	5	
. oropharyngeal aspiration	2	additional 15'
. oroendotracheal intubation	5	
. assisted ventilation with bag	p.m.	
. nasogastric tube	3	
. bladder catheterisation	4	
. chest tube placement	6	optional 18'
. pericardiocentesis	5	

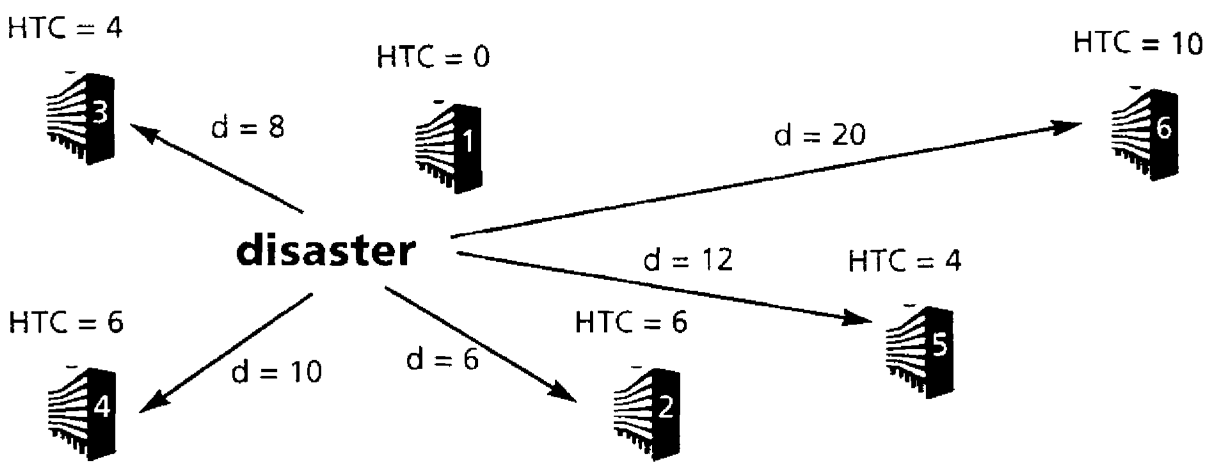
T2 If no adequate first-aid measures are to be taken disturbances of vital functions are to be expected within 4-6 hours

. orientation & positioning	1	
. hemorrhage control	3	
. fracture immobilisation	5	maximal 13'
. intravenous line	4	

* round off minutes

Estimation of the number of ambulances needed at disasters*
or
Calculation of the medical transport capacity (MTC)

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF PREHOSPITAL AND DISASTER MEDICINE (1996)



Hospital	**Distance**	**HTC**	**Total HTC/hour**
1	0	0	0
2	6	6	6
3	8	4	10
4	10	6	16
5	12	4	20
6	20	10	30

Based on a proper victim allocation plan.

N disaster victims have to be transported within a clearance time of *T* hours by *X* ambulances provided each ambulance carries n victims and needs *t* hours to overcome *d* (average).

There is a number of reasons why it is important that the ambulance capacity available in the event of a disaster should match the need for medical transport. First and foremost, the "normal" ambulance service must be continued for as long as possible. Apart from making financial sense, this also provides a balanced response to the demand for transport. After all, the personnel sent to a disaster is removed from the normal service, and sending too many not only depletes this service but also costs more money.
Secondly, the methodology could be applied in the preparedness phase utilizing the model of the chain of medical care for various scenarios in different areas (centres) and sites at risk (airports, stadiums, industrial)

METHODOLOGY

Since the number of ambulances needed at a disaster (X) is directly proportional to the number of victims requiring hospital treatment (N) and the average travelling time between the disaster site and the surrounding hospitals (t), and is inversely proportional to the number of victims who can be transported on each journey (n) and the total time (T) available for the transportation (clearencetime) of N, the following formula can be

applied: $X = \frac{N.t}{T.n}$

The example indicates that this formula is in principle mathematically "sound". The formula would appear to make it possible to calculate the number of ambulances needed to transfer victims to nearby hospitals.

We say "would appear" because it is very difficult to determine the number of victims requiring hospital treatment (N) and the average travelling time (t) to local hospitals. This is not the case with the other variables T and n. Since triage I victims must be stabilised within the "golden hour" and then - like the triage II victims - treated in hospital within four to six hours, T can be set at a maximum of six hours. The number of triage I and II patients requiring transport by ambulance on each journey (n) has been set at one in the Netherlands, although a triage III victim might be taken along as well. However, the calculation is based primarily on triage I and II victims (who require hospital treatment).

if	N = 100 victims requiring hospital treatment	
	n = 1 victim per ambulance per journey	X=16
	T = 6 hours to transport 100 victims	
	t = 1 hours' average travelling time	

Sample calculation of number of ambulances required

However:

N and **t** are difficult to estimate,

while n and T are fixed!

The problem is thus to determine N and t. The number of victims (N) can only be estimated. It has been found in practice that this number is usually underestimated in the case of natural disasters, while it is generally overestimated in disasters resulting from human activity (= Rutherford's Rule). The first estimate in the event of a natural disaster usually refers to only a proportion of the affected area. Hours or days later it becomes clear that there are more victims than originally thought. The opposite applies to man-made disasters. Examples of the two include the floods in 1953 and the Bijlmer air crash in 1992.

However, we can do no more than bear this general rule in mind during the initial determination of the number of victims, and it cannot help to give a more precise estimate of N.

Determining the average travelling time (t) is also problematic. Several hospitals will be involved in any disaster. The distance from the site to the hospital differs from one disaster to another, so an average distance will have to be worked out and an average driving speed applied, while the time taken to embark and disembark will also have to be taken into account. At any rate, the victims will have to be divided among the hospitals in the area in such a way that the capacity to treat them is not exceeded. This is done on the basis of a victim distribution plan.

A more accurate estimate of N and t will ultimately also lead to a more accurate estimate of the number of ambulances required.

$$\pi R^2 = \frac{N \times 246}{T \times 12}; \quad R^2 = \frac{N \times 246}{T \times 12 \times \pi} = \frac{N \times 80}{T \times 12}; \quad R = 2{,}6\,\frac{\sqrt{N}}{\sqrt{T}}$$

Calculation of the radius of the area comprising the hospitals needed to treat the number of victims (N) requiring hospitalization and based on an average hospital treatment capacity (HTC) of 12 T1 and T2 victims per hospital within a clearance time of T hours.

$$t = 0.09\,\frac{\sqrt{N}}{\sqrt{T}}\text{ hour}$$

Based on figures valid only for the Netherlands, however, each district, region, municipality, should introduce their own figures.

DETERMINING THE AVERAGE TRAVELLING TIME (t)

There are some 150 hospitals in the Netherlands unevenly spread over some 37,000 km^2. One hospital therefore serves an average area of 37,000/150 = 246 km^2, with a radius of approximately 9 km.

In total there are some 60,000 beds, with each hospital having around 400. In a disaster response plan the medical treatment capacity has been set at 3%* of the bed capacity per hour, so about 12 triage I and II victims per hour can be treated adequately and efficiently for a period of T hours. This means that an average hospital with 400 beds, situated in an area with a radius of some 9 km, can treat approximately T x 12 triage I and II victims adequately and efficiently, provided they have a well-rehearsed disaster response plan. If there are N victims, where N is taken to be multiple of 12 and T is given in hours, then N : T x 12 hospitals are needed to handle the triage I and II victims. These hospitals will be in an area of (N : T x 12) x 246 km^2. The radius of this area is calculated as shown.

The average distance between the disaster site and the surrounding hospitals is thus:

$$0.7 \times 2.6 \frac{\sqrt{N}}{\sqrt{T}} \text{ km}$$

which has to be covered twice (the figure 0.7 is a mathematical given).

If this distance is driven at an average speed of 40 km/h, the average travelling time is:

$$\frac{2 \times 0.7 \times 2.6 \sqrt{N}}{40 \times \sqrt{T}} = 0.09 \frac{\sqrt{N}}{\sqrt{T}} \text{ uur}$$

Thus, with 289 victims who must be ferried to hospital in six hours the average travelling time per ambulance will be:

$$\frac{0.09 \times 17}{2.5} = 0.6 \text{ hour} = 36 \text{ minutes}$$

* On the basis of a large number of exercises carried out at the time, although 3% is now regarded as too high.

Estimating numbers of disaster victims

Basic figures for contingency planning

		IMMOVABLES	range[1]
residential area[2]	per hectare	low-rise buildings	20-50
		high-rise buildings	50-200
business	per hectare		0-800
industrial area	per hectare		0-200
leisure area	per type	stadium	-[7]
		discotheque	-
		camp-site	-
shops	per type	department store	-[7]
		arcade	-

		MOBILE OBJECTS	
road transport	per 100 M (lenght)	multiple collision	5-50
	per type [3b]	coach	10-100
rail transport[4]	per type	single deck	5-400
		double deck	10-800
air transport[5]	per type	small	10-30
		large	150-500
inland shipping[6]	per type	ferry	10-1000
		cruise ship	200-300

1 depends on date and other local circumstances.
2 combination of number of residents per house (1.8-2.8) and number of houses per hectare (30-70)
3a per car: length 5m and 1.5-3 passengers (see 1)
3b (articulated) local bus or (articulated) double-decker bus
4 carriage of 3 or 4 wagons (see also 1)
5 seat occupancy 70%
6 seat occupancy 80%
7 awaiting further research

DETERMINING THE NUMBER OF VICTIMS REQUIRING HOSPITAL TREATMENT (N) (see also chapter on Rutherford's Rule)

Whereas the average travelling time between the disaster site and the hospital can be approximated by means of calculation, this is not the case when it comes to the number of victims (N). This requires an entirely different approach, which for the time being must be based on empirical information.
The population density in the affected area is the most important parameter. The population density in the Netherlands varies form 0 persons per km² in some parts of Drenthe and Gelderland to roughly 100,000 per km² at a packed football stadium or rock festival. The average density is just over 400 per km², giving each inhabitant an area of 50 x 50 metres (2500 m² or a quarter of a hectare).

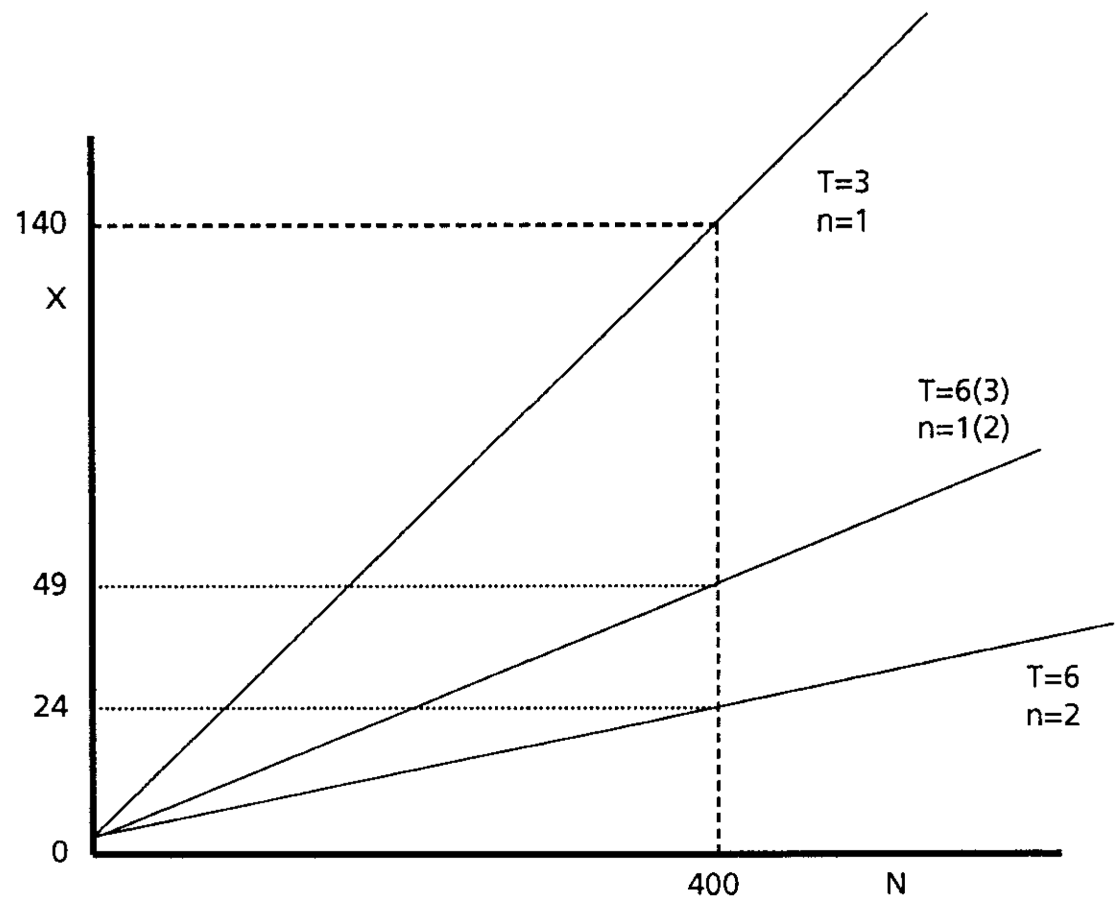
But this in itself tells us nothing about the density in a residential area, building, plane, train, on a motorway (in the event of a multiple pile-up) or industrial site, or the density within and outside working hours. This information has been gathered and is presented in the table. However, knowing the population density of a particular area does not tell us the number of victims requiring hospital treatment.
In road traffic accidents, the percentage distribution in terms of seriousness of injury is: 5-10% fatalities, 10% triage 1, 20% triage 2 and 60% triage 3 victims.
Of course there is a great deal of variation in this distribution. However, one can generally expect a higher proportion of deaths and serious injuries in the event of a fire or explosion; in contrast, civil unrest tends to lead to more minor injuries. (see chapter on Evaluation of disasters)
On the basis of the above data we can say that in the average disaster, 40% of the victims will require hospital treatment (10% triage I and 20% triage 2 victims). To be on the safe side, if we can estimate in the area where the victims are situated, the population density , the size of the disaster site and/or the number of units affected (cars, train, carriages, planes), we can assume that all the people present in the area have been affected and half of them will need hospital treatment. In the case of fire, explosions, plane crashes and collapsed buildings, the proportion could be as high as two-thirds; one-third would be an appropriate figure in the case of civil unrest.
On the other hand, we should point out that it takes a long time to rescue the victims of certain types of disaster (collapsed buildings, train crashes). This means that the victims will not all require transportation at once, so that fewer ambulances will be needed.
The formula can now be applied as shown in the table, and can be represented graphically as shown in the figure.

$t = 0{,}09 \frac{\sqrt{N}}{\sqrt{T}}$; T = 6 uur; n = 1:

$$X = \frac{N \times t}{T \times n} = \frac{N \times 0{,}09 \sqrt{N}}{T \times \sqrt{T}} = 0{,}09 \ \frac{N\sqrt{N}}{T\sqrt{T}}$$

$$X = \frac{0{,}09 \times 289 \sqrt{289}}{6\sqrt{6}} = \frac{0{,}09 \times 289 \times 17}{6 \times 2{,}5} = 29 \text{ ambulances}$$

The formula for determining the number of ambulances needed, on the basis of 289 victims requiring hospital treatment.



Relationships between the number of victims requiring hospital treatment and the number of ambulances needed with different values for T and n.

Discussion

In the worst-case scenario, several disasters might happen simultaneously or in succession, perhaps as a result of acts of terrorism or a chain reaction, leading to a shortage of ambulances. This can be prevented by more accurate prediction of the number of ambulances needed at a disaster. But before any disaster occurs, more accurate prediction can be used in the preparation stages of disaster response in the form of policy instruments. One might, for instance, focus on certain areas of high risk, such as airports, industrial sites, motorways etc. where N and t can be roughly determined in advance and, therefore, so can X. The graph clearly shows that, the shorter the "clearance time" (T), the greater the number of ambulances needed; conversely, the more victims taken to hospital in each ambulance (n), the lower the number of ambulances required.
We can also calculate that a disaster in NL involving more than 1,500 victims requiring hospital treatment cannot be cleared in six hours by civilian ambulances alone. The entire ambulance fleet of around 325 would have to be called in, and extra support from the military would be needed.

The general formula $X = \frac{N.t}{T.n}$ applies for numbers (X) of any kind of vehicle

(ambulances, lorries, busses) transporting a total amount (N) of "things"
(men, patients, material), where each vehicle is carrying a part of these things (n), taking an average transporttime (t) within a certain timelimit (T). Off course, T should be a multiple of t and N a multiple of n. One could immediately see that when N equals n the formula becomes X = T/t and when T equals t the formula will be X = N/n, while X = 1 for T = t and for N = n.
When we are dealing, however, with victims who should be treated within certain time limits, preferably, 1-2 hours for triage 1 and 4-6 hours for triage 2 victims, this general formula has to be modified.
In this respect and as mentioned before t and N are difficult to estimate, however, N could be obtained empirically, while t could be calculated in a certain area in terms of N and T, provided we are dealing with triage 1 and 2 vicitms to be treated in a certain number of hospitals with a given hospital treatment capacity, i.e. the number of victims that can be treated per hour during a certain period T. For The Netherlands t could be set

at $0{,}09 \cdot \frac{\sqrt{N}}{\sqrt{T}}$

For a remote area the size of The Netherlands with, say 3 hospitals of 100 beds each, where a plane crashed with 36 triage 1 and 2 victims, one can immediately see that t will be larger than T, which makes the formula worthless. Where will be the limits now for this formula? In order to answer this question further mathematical analysis of the formula is required, which will be the subject of a next study.

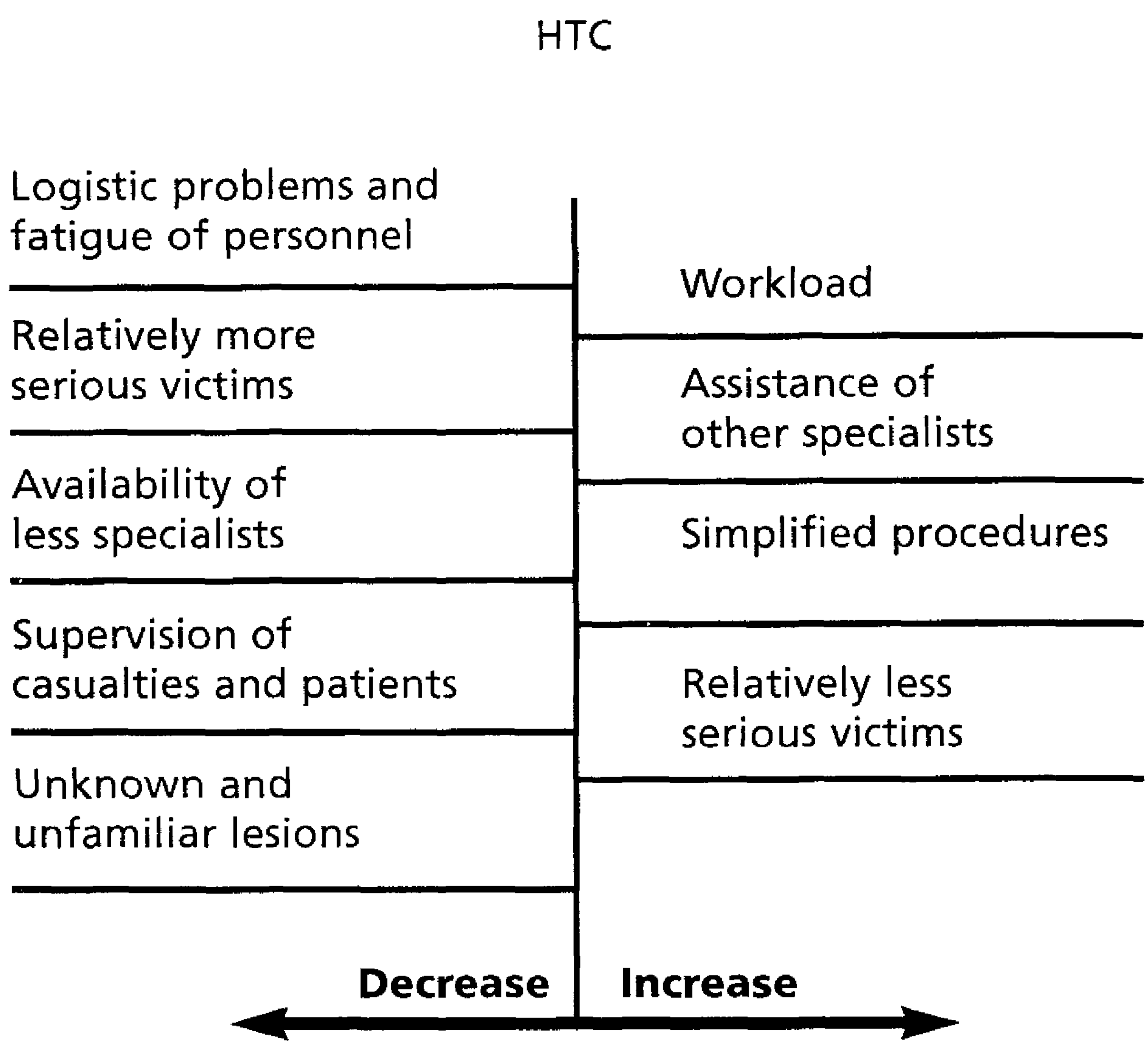
THE HOSPITAL TREATMENT CAPACITY (HTC)

How to calculate the hospital treatment capacity (HTC) for mechanical injuries for a given hospital.

		Number (N)	Weight(W)	N x W
1	Total number of beds		1/3000	
2	Number of surgical beds		1/250	
3	Number of intensive care beds		1/20	
4	Number of operating theaters		1/10	
5	Number of operations per year		1/20000	
6	Number of surgeons		1/5	
7	Number of anaesthesiologists		1/4	
8	Number of surgical residents		1/10	
9	Number of other surgical specialists		1/10	
10	Number of A & E patients per year		1/10000	
			Total	

The last phase in the chain of medical care is the hospital. In an average hospital, either large (1000 beds) or small (100 beds) doctors, nurses and paramedical personnel are working. In these hospitals the basic specialists are usually available, like surgeons and internists. In a day-to-day situation these specialists can handle the majority of accidents and emergencies. Depending on the type of emergency, whether the patient has suffered a mechanical, chemical, nuclear or biological lesion, the hospital treatment requires a certain period of time. The treatment of a patient with mechanical injuries, like fractures or damaged organs, requires more time than the treatment of a patient with an infectious disease, like cholera.

For mechanical injuries this time has been determined, for the other types of injuries (lesions) this time is unknown. This hospital treatment capacity (HTC) is the number of patients which can be treated per hour and per 100 beds, because this treatment is related to the number of beds in a general hospital. Only for patients with mechanical injuries this HTC is known for a normal day-to-day situation and amounts 0.5-1.0 patients per hour, per 100 beds. However, with a well practiced disaster procedure (see the appropriate chapter) this HTC can be increased to 2.0-3.0 patients per hour and per 100 beds. This figure has been obtained through many exercises and is mainly determined by the number of surgeons, anaesthesiologists specialised nurses, specific accomodation and some other features.


HTC
Logistic problems and fatigue of personnel
Relatively more serious victims
Availability of less specialists
Supervision of casualties and patients
Unknown and unfamiliar lesions
Workload
Assistance of other specialists
Simplified procedures
Relatively less serious victims
Decrease
Increase

Of course, this HTC for mechanical injuries is influenced by many factors. Under these circumstances hospital personnel work harder, which increases HTC. Eventually, however, fatique will decrease this capacity. Certain disasters, like explosions, may cause relatively more seriously injured victims, hampering HTC; on the other hand less severely wounded like civil disturbances, may lead to the reverse.

One of the measures to be taken in a hospital disaster procedure is the discharge of those patients who are supposed to be discharged one of the next days. This results in relatively more serious hospital patients. Together with those being rushed in following a disaster, this means that the supervision of operated casualties and hospital patients will be more timeconsuming, thus decreasing HTC. Instead of performing sophisticated reconstructive surgery the surgeon may decide, under the given circumstances, to utilize simplified procedures, which increases HTC. This increase may also be the result of the assistance of other "cutting" specialists, like gynaecologists and urologists.

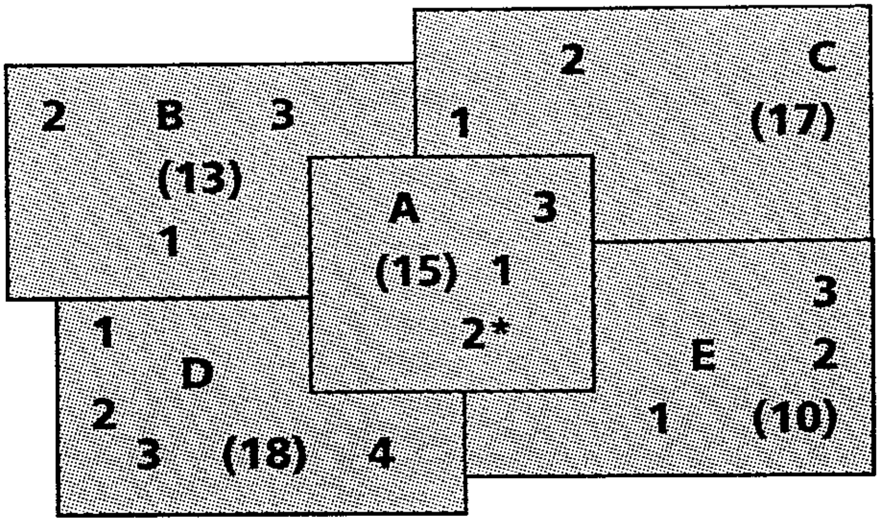
Another approach for calculating the HTC for mechanical injuries, might be the one used for determining the medical rescue capacity, as described in the appropriate chapter.

As mentioned earlier the HTC for other types of injuries, chemical, nuclear and biological, is unknown. Research in this field is therefore imperative.

AMBULANCE SUPPORT

&

VICTIM DISTRIBUTION



Ambulance regions with their total number of ambulances

Figures between brackets are numbers of ambulances; other figures are representing hospitals

1	2	3
A	15	8
E	10	13
D	18	22
C	17	30
B	13	36

When a disaster occurs at * a cumulative total of 36 ambulances can be obtained from neighbouring regions

1. region
2. total number of ambulances
3. cumulative total based on a 50 % availability

Ambulance Support

Usually a certain number of ambulances are constrained to a certain region. Each ambulance region is therefore surrounded by other ambulance regions, at least in most cases in those countries with an Emergency Medical System. The number of ambulances in such a region is determined by the daily need for these vehicles and some spare ones.
In case of disaster the need for ambulances increases considerable and support from the surrounding regions is necessary. Therefore each ambulance region should have a so called ambulance support plan where and how many ambulances can be obtained in such a situation. On the other hand, these regions should not be deprived of too many ambulances, since the daily routine requires a certain minimum number for emergency cases in their region. As a general rule not more than half the number of ambulances could become available for a certain period of time.
An Ambulance Support Plan is represented by een simple table, containing the telephonenumbers and the maximum number of available ambulances of the surrounding ambulance regions. The sequence, of course, of alerting the neighbouring regions is also important; the region closest tot the disaster site should be alerted first, followed by the second closest and so on. In this way a cumulative list of available ambulances could be produced in a short period of time.
A summary is presented in the figure and table.

Victim Distribution Plan

1	2	3	4	5	6
Region	**Hospital**	**No. of beds**	**HTC**[1]	**Cumulative HTC**	**Distance from disaster site**
A	1	500	15	-[2]	1 km
	2	300	9	9	3 km
	3	200	6	15 (9 + 6)	6 km
E	1	400	12	27 (15 + 12)	6 km
	2	600	18[3]	45 (27 + 18)	9 km
	3	100	3	48 (45 + 3)	10 km
D	etc				
C	etc				
B	etc				

(1) based on 3 per 100 beds per hour for a hospital with basic specialisms (see appropriate chapter)

(2) the nearest hospital should be exempt because of overload by walking victims

(3) neurosurgery and cardiac surgery present

Column 1, 2, 3 and 4 can be filled-in already for each ambulance region; column 5 and 6 should be filled-in when disaster strikes.

Victim distribution

Since it is of paramount importance that victims in a mass casualty situation receive medical treatment adequately and efficiently in the shortest possible time, each ambulance region should possess a victim distribution plan.
Such a plan provides the neighbouring hospitals around the disaster site with an appropriate number of victims, according to their treatment capacity.
In this way these hospitals will not receive more victims than they can handle. The hospital treatment capacity (HTC) is expressed as the number of victims to be hospitalized and treated, according to current medical standards, per hour (see appropriate chapter). Since the nearest hospital will be overloaded by walking victims, this hospital should be exempt as much as possible.

For drafting a victim distribution plan certain data are needed:

- the location of the disaster site;
- the location of the neighbouring hospitals;
- specific diagnostic and therapeutic facilities of these hospitals, like neurosurgery and cardiac surgery;
- and last but certainly not least, the treatment capacity of each hospital.

Some of these data can be collected beforehand already, which makes the final drafting of the plan easier and quicker.
An example of such a drafting is shown in the table.
For the number of ambulances needed to transport a certain number of victims a formula has been developed, which is explained in the subchapter "Medical Transport Capacity" in the chapter on the Chain of Medical Care and its Capacities.
Computerisation of these principles could ease the procedure even more.

A HOSPITAL DISASTER PROCEDURE

Hospital **External** Disaster Procedure	Hospital **Internal** Disaster Procedure

- Both procedurers have 4 phases
- Hospital at the end of the chain of medical care
- Hospital Treatment Capacity: ± 3%
- Disaster Committee

A hospital disaster procedure is in some countries legally obliged, in others only morally obliged, while in most countries it is non-existent.
There are two types of procedures: - a management procedure for the admission and treatment of large numbers of victims, preferably not exceeding the hospital treatment capacity. This is the hospital *external* disaster procedure.
And a management procedure for coping with an internal accident (fire, explosion) or an accident nearby, usually by evacuating (parts of) the hospital. This is the hospital *internal* disaster procedure.
Both procedures have 4 phases: alarm, preparation, execution and evaluation.
The hospital is situated at the end of the chain of medical care, with a certain Hospital Treatment Capacity (HTC), which is determined by personnel, material and methods. This HTC is also determined by the type of injury: mechanical, chemical, nuclear and microbial. As discussed in a previous chapter this HTC is roughly 2-3 % per hour, i.e. 2-3 victims with mechanical injuries per 100 beds per hour could receive adequately and efficiently surgical treatment provided trained personnel, sufficient material and an exercised hospital disaster procedure.
The HTC for chemical, nuclear and microbial patients is unknown so far.

Each hospital should have a disaster committee comprising a board member, two specialists and representatives of nursing, domestic and technical staff and administration. Their task is to draft a disaster procedure, to organize exercises, to function as troubleshooter when real, to coordinate with external parties concerned and to inventory risks.

- Verification of disaster alarm
- Superintendent and/or specialist on duty/call should approve action
- Snowball principle
  1 person alerts 2 others and each of them 2 others again, etc. (operator alerts only a few people!)
- Use of other means of alerting personnel

ALARM

A large general hospital is in a position to enlist a smaller or larger number of staff according to information coming in regarding the nature and magnitude of a disaster. This so-called "balanced response" is difficult to realize in a medium-sized district hospital. In the latter case, restriction of manpower is likely to determine an "all-or-none response".

The disaster alarm, coming from outside the hospital, should be relayed to the duty surgeon. Only he is in a position to decide whether or not the disaster plan should be set in motion. Depending principally on the number of surgeons, operating-room staff and casualty personnel, the disaster plan can be initiated on the receipt of an unexpectedly large number of injured.

If the disaster message comes in by phone, it should be verified in order to avoid unnecessary activities.

The superintendent on call/duty should approve action.

The alerting procedure itself should follow the snowball principle as described in the appropriate chapter.

Having decided that a disaster situation does in fact exist, the duty surgeon initiates the procedure by telephoning others - telephonists, surgeons and casualty staff. They, in turn, alert by telephone other members of the hospital staff. A uniform procedure for every hour of the day should be aimed at; this is by far superior to two separate procedures, one for normal working hours and the other for nights and weekends.

Other means of alerting personnel should also be considered.

- clear command structure/coördination by disaster committee
- adherance to normal hospital routines
- control of routing: victims
  ambulances
  visitors
- communications guaranteed
- discharge of patients
- clearing of spaces
- keep track of logistics
- simple brief instructions for each department

EXAMPLE OF SUCH AN INSTRUCTION

Hospital Steward's Department

1 Alerted by porter
2 Alert mortuary technician and restaurant personnel
3 Arrange reception of patients requiring only out-patient treatment
4 Reception of persons seeking injured relatives
5 Reception of the press (No information to be given: information to be relayed only by the medical superintendent).
6 Provision of coffee and rolls for all personnel involved and working overtime

Preparation

When drawing up a disaster plan one should endeavour to adhere as far as possible to normal hospital routine. Hospital personnel should perform duties for which they have been trained and in a location in which they are used to working. The involvement of too many individuals should be avoided.

The flow of T1, T2 and T3 victims should be separated.

The areas for these groups should be cleared.

Those patients who are planned to be discharged the next day, should be discharged immediately.

The routing of ambulances has to be controlled, as well as the elevators on the entrance floor and the main entrance(s).

Communication between hospital personnel, particularly between the members of the disaster committee who are acting as troubleshooters, should be quaranteed. This could be achieved by limiting the use of telephone as much as possible.

Uniform external contacts, preferably through one channel should be established.

Material (supplies) must be used as economic as feasible.

The working instructions for each section should be brief and simple to understand. An example of such an instruction is given in the table.

- every admitted T1 and T2 victim should be accompanied by a nurse
- uniform triage throughout the hospital
- simplification of treatment
- standardization of methodes
- appointment of a medical information carrier for the acquisition, processing and retrieval of medical information from the victims
- this information should be channeled to the outside world (press, police, family) through the superintendent of the hospital

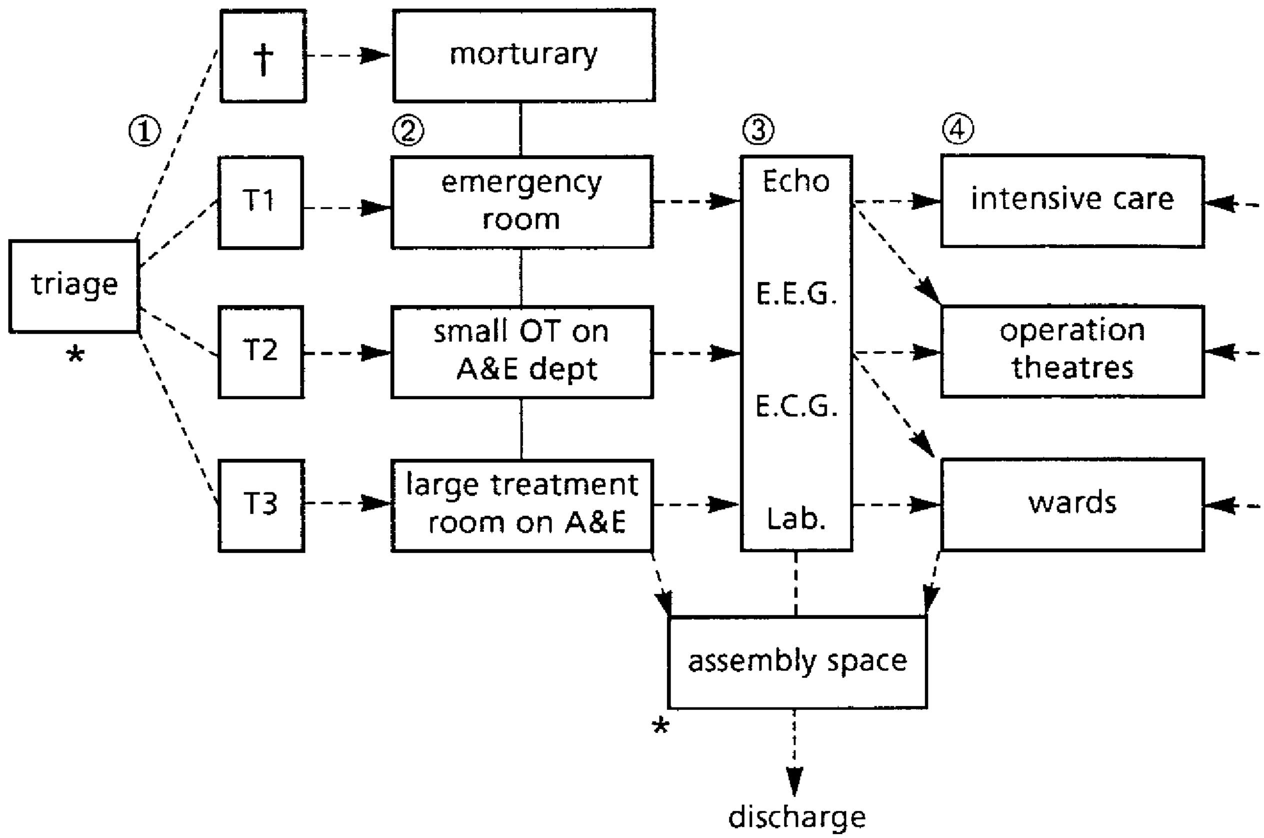
EXECUTION

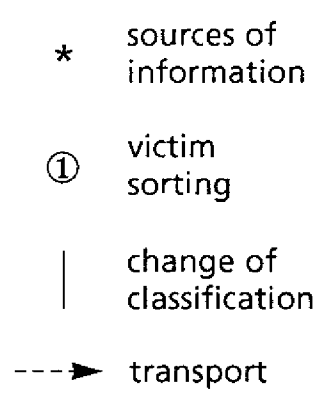
Having accomplished his or her reporting, each member proceeds to the preparatory duties in order to ensure that a state of readiness for reception of the injured can be achieved within 15-30 minutes. Responsibility for leading the disaster organization should be vested in one individual, preferably the duty surgeon. The latter carries out the triage, which is also described in a previous chapter. Repeated examination of the victims by the surgeons and/or other specialists is important in the recognition of latent or developing lesions.
Responsibility for dealing with medical information should rest in the hands of one doctor. This is a very important aspect of the organization and information regarding deceased or injured relatives should be relayed to the family, police and press through this channel only. The administrative procedure should fulfil certain requirements:

- the personal particulars and the medical notes relating to each patient should be filed together,
- initially, it is convenient to substitute a code or number for the patient's personalia,
- personal particulars are collected and recorded by administrative staff,
- medical notes are recorded by the member of the nursing staff accompanying each T1 and T2 patient,
- having collected and checked the personal and medical data, the medical information officer relays them to the public relations officer (e.g. the medical superintendent),
- the locations where information can be assimilated most readily lie at the beginning and at the end of the casualty routing inside the hospital.

Near the A&E Department a pool of nurses must be created, so that each admitted T1 and T2 victim can be accompanied by a nurse, while being routed through the hospital.
Casualty routing is represented schematically.
Triage results in division of the victims into 3 groups.
Class T1 victims with disturbed vital functions are taken to the emergency room adjoining the A&E Department where facilities exist for cardiac monitoring, defibrillation, ventilation of the lungs, and other resuscitatory measures. Response to treatment results in transfer to the intensive care unit or the operating theatre.
Class T2 patients are brought to the casualty room on the A&E Department where they can be treated prior to admission, whether or not operation is indicated.
Class T3 patients will be walking cases who, after treatment in the large treatment room, may be allowed to proceed home via the assembly space.

Diagram of victimflow





Initial classification occurs during triage; subsequent appraisal occurs directly thereafter in the A&E Department: in the rooms reserved for class T1, T2 and T3 victims. Further reappraisal occurs in the diagnostic departments and yet again in the intensive care unit, ward, or operating theatre. The patient is thus subjected to continuous reappraisal until the ultimate diagnosis or diagnoses are decided upon.

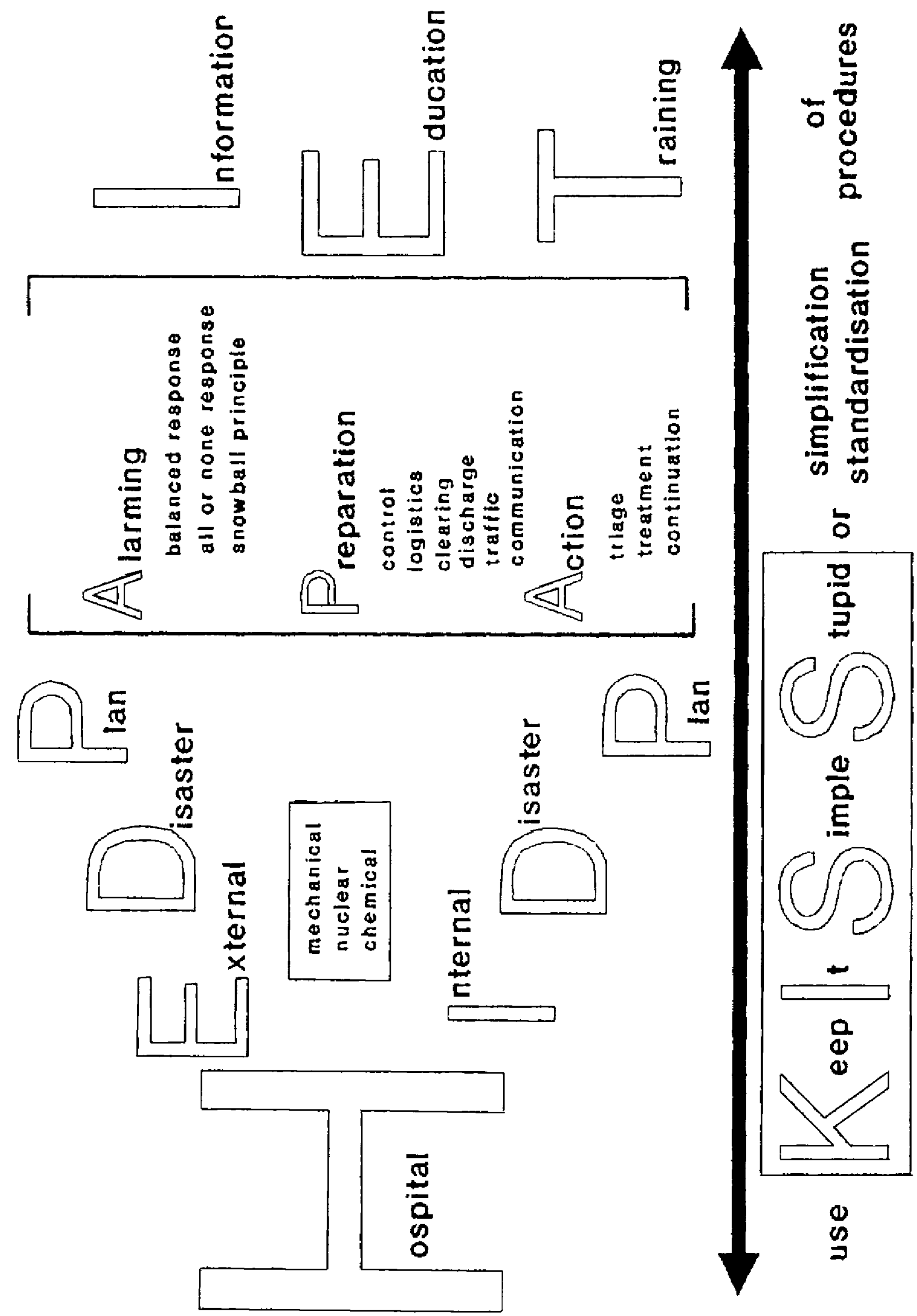
Diagnostic and therapeutic procedures have to be *simplified,* c.q. a simple fracture is reduced and provisionally immobilized, a large wound is desinfected and covered sterile. Some hours later, during a less hectic moment, these should be treated properly.
By *standardisation* is meant that standard procedures are to be utilized for drips, antibiotics, analgesics, anticoagulants and the like.

SPECIFIC SITUATIONS

- **nuclear disasters**
  - (fixed or mobile installations)
  - selfprotection & decontamination

- **chemical disasters**
  - (fixed or mobile installations)
  - selfprotection & decontamination
  - antidotes
  - respirators

- **microbial disasters**
  - epidemics (cholera, typhoid)
  - acute salmonellosis (planes, ships)
  - selfprotection & sterilisation



Hospital
External
Disaster
Plan
mechanical
nuclear
chemical
Internal
Disaster
Plan
Alarming
balanced response
all or none response
snowball principle
Preparation
control
logistics
clearing
discharge
traffic
communication
Action
triage
treatment
continuation
Information
Education
Training
use
Keep it Simple Stupid
or
simplification
or
standardisation
of
procedures

Evaluation

following a real disaster or following an exercise

- periodic evaluation and up-dating of names, addresses and telephone-numbers of essential hospital personnel;
- periodic exercises of parts of the hospital disaster procedure (e.g. the alarm-procedure, the preparation or the execution phase only);
- once per two years a big exercise involving all services concerned: fire brigade, police, ambulances;

preferably national coordination and standardisation of the exercises.

Hospital internal disaster procedure

- accident in the hospital itself (fire, explosion) or near-by (chemical or nuclear plants)
- same procedures in case of multiple victims and/or
- evacuation of parts or the whole hospital:
  - horizontal evacuation
  - vertical evacuation
- collaboration with the fire brigade

PUBLIC HEALTH MEASURES FOLLOWING A NUCLEAR ACCIDENT*

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF EMERGENCY MEDICINE (1994)

- Community profile
- Intervention levels
- Action zones

Curative measures

On-site and near-field

During transportation

In the neighbouring hospitals

N-teams

Preventive measures

Public information

Sheltering and other protective measures

Iodine prophylaxis

Evacuation

Decontamination

Public health measures after a nuclear accident or disaster

On the night of 25 April 1986, there was an explosion in one of the four nuclear power reactors in Chernobyl, Ukraine. Twenty-eight people were killed outright; another 3 died within a few days; and approximately 135 were diagnosed as suffering from acute radiation sickness. Only after satellite photos and readings of increased radioactivity, first from Sweden and later elsewhere, had indicated that there may have been a nuclear accident, was the world officially informed of what had happened. The event had a worldwide impact. For thousands of scientists, it meant research opportunities in many different fields: from pure nuclear physics to the study of psychosocial problems, and from genetics to epidemiology. Much of this research has been conducted by the Soviets themselves. However, scientists from outside the Soviet Union often under the auspices of such international agencies as the International Atomic Energy Agency and the World Health Organization, have also conducted research, both in the field-that is, in the region surrounding Chernobyl-and in laboratories. What is more, the scientists have been outnumbered by journalists, who have churned out more half-truths about Chernobyl than accurate information.
Before Chernobyl, the world was busy protecting itself from nuclear weapons. Since the accident, there has been an increasing focus on safety in nuclear power stations, which have rapidly increased in numbers in recent years. Within a 1,000-km radius of the Netherlands, there are about 120 operational nuclear power stations. Dozens of new ones are currently in construction, and dozens more, mainly in Eastern Europe, are now obsolete.

Public health measures following a nuclear accident include medical and preventive measures, together known as "direct measures", which are concerned with meeting medical needs in the direct vicinity of a nuclear accident. This chapter deals with the medical, or curative, measures and the medical and medico-organizational aspects of the preventive measures.

Community profile

=

local environment:
- population density
- age distribution
- roads, railways, waterways
- types of dwellings and other buildings
- relief agencies

Action zones

=

the parameters of the community profile determine the borders of the action zone where public health measures are to be taken.

Intervention levels

=

radiation levels indicating which measures in the action zones should be taken.

DEFINITIONS

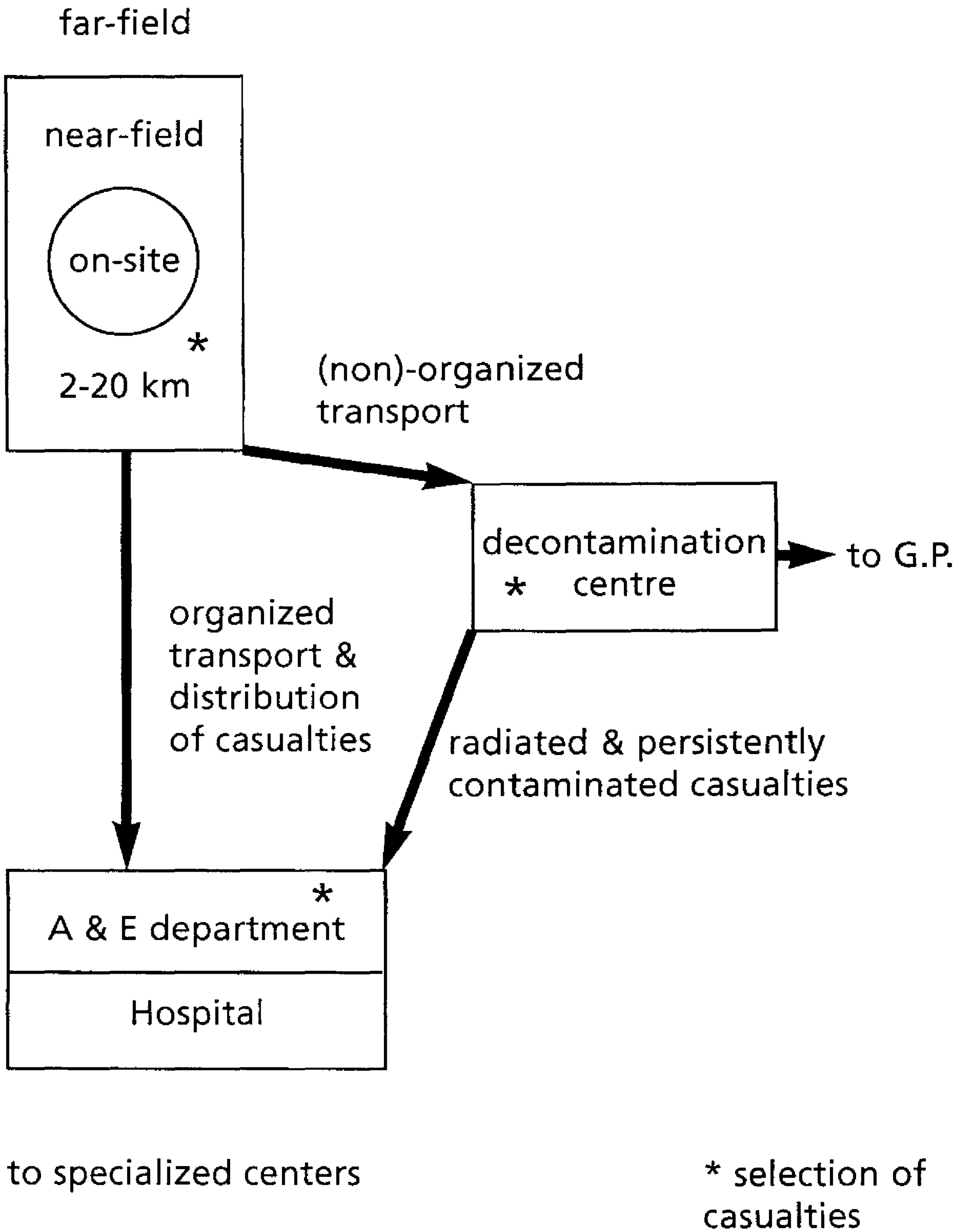
A "nuclear accident" refers to any accident involving equipment used to extract, manufacture, consume, store, or transport nuclear fuel and radioactive substances. All of these processes can result in release of radiation, which in turn can increase risks to human health and the environment. Reducing or eliminating this increased radiation risk requires coordinated effort on the part of agencies or organizations in various disciplines.
The level of administrative coordination-that is, the level at which radioprotective measures are decided and emergency measures managed-depends on the scale, or the possible scale, of the accident. Potential accident locations are divided into two categories ("A and "B") according to the scale of the environmental risk and the potential national and international impact of accidents.

Category A
* nuclear power stations and research reactors;
* nuclear power stations in border areas;
* nuclear-powered spacecraft or parts of spacecraft that have crash-landed;
* nuclear weapons in storage or transit;
* nuclear installations or sources farther away from the borders.

The central government is responsible for administrative coordination in the case of category A locations, since accidents involving these locations are likely to have a nationwide, and possibly international, impact.

Category B
* uranium enrichment plants;
* plants for the production, processing, and storage of radioactive material;
* locations where radioactive material are used;
* the transport of radioactive material and nuclear fuel.

In the case of category B locations, municipal officials are responsible for administrative coordination, since the impact of accidents in these locations is unlikely to extend beyond municipal boundaries.
A nuclear accident's impact on human beings and the environment is determined by the strength of the nuclear power source, the nature of the radiation released, the type of weather, and the "community profile".
"Community profile" refers to the local environment: population density and age distribution, roads, railway, waterways, types of dwellings and other buildings, and the relief agencies locally available. These parameters determine the borders of "action zones" within which measures are to be taken. The parameters are especially important in the case of category A locations.
The fire services are equiped to measure radiation levels, while a medical assistance team is manned with a physics radiation expert. Both groups help to establish the levels of radiation in the environment. Since conditions are bound to vary from accident to accident, individual measures are generally ranges from which the appropiate intervention level can be chosen. The levels determine the measures to be taken in these action zones and can therefore be regarded as aids to decision-making. Intervention levels are determined in light of the advantages and disadvantages that may result from a particular measure: risk reduction is weighed against social disruption and damage to the economy and public health.


far-field
near-field
on-site
*
2-20 km
(non)-organized transport
decontamination
* centre
to G.P.
organized transport & distribution of casualties
radiated & persistently contaminated casualties
*
A & E department
Hospital
to specialized centers
* selection of casualties

THE MEDICAL RELEIF CHAIN

Serious nuclear accidents, like any other type of disaster, will lead to the establishment of a chain of medical relief. This chain, which starts with coordinated medical treatment and nursing care at the scene of the accident and ends in hospital care, can be divided into three more or less autonomous medico-organizational systems. They are: medical care at the scene of the accident; transportation of victims to various hospitals; and medical care in the hospitals themselves. In the theory, the same medical relief chain and the same three organizational systems apply to all accident, whether in category A or category B locations. However, there is a complicating factor: when an accident occurs, radioactive material is released in clouds made up of water droplets or dust particles, which are invisible and drift according to the weather. This raises the risk of human contamination, both at the scene of the accident ("on-site") and in the immediate surroundings ("near-field"). Victims must be decontaminated at designated decontamination centers.

Two medical relief chains therefore arise: one for the injured, who might also be suffering from radiation exposure and contamination, and one for the apparently uninjured, who might nevertheless be suffering from contamination. The first chain includes the allocation and transport of patients to various hospitals. The second chain involves the transport of the uninjured to decontamination centers. The selection of victims for each of the two chains is therefore important, both on-site and in the nearfield, and later in the decontamination center and in the hospital.

Radiation		Contamination
α-rays β–rays γ–rays		radioactive dust, droplets, aerosols
↓		↓
partial or		external
whole body		clothes, shoes
burns	←	skin, mucous membranes
and		and
		internal
systemic effects	←	inhalation ingestion

Radiated casualties
do not endanger their environment

Contaminated casualties
do endanger their environment

Medical Measures

The nature of the injuries suffered determines the curative measures to be taken. If an accident involves an explosion or fire in either a category A or category B location, the injuries may be mechanical, thermal, nuclear in nature, or combinations of all three. Mechanical and thermal injuries are not discussed further here. However, it should be noted that disorders of the vital functions-repiration and blood circulation-take priority over all other injuries. Whatever nuclear injuries are suffered, these disorders must be treated first.

Combinations of mechanical, thermal, and nuclear injuries resulting from explosions or fires occur only on-site. In the near-field, victims will have been exposed to radioactive contamination but will have no direct mechanical or thermal injuries. The radius of the near-field may vary from 2 to 20 kilometers, depending on the source strength. The geographical area that is affected within the defined radius will depend upon the wind direction and velocity. The near-field constitutes the "action zone" in which the preventive measures discussed below are instituted. Beyond this zone is the far-field, which can be affected both directly, for instance, by increased radioactivity in the atmosphere, or indirectly, by the import of consumer goods that have been contaminated by radioactivity.

Nuclear injuries, which are often not immediately visible, are caused by external exposure to radiation and internal or external contamination with radioactive material. Radiation exposure can affect part of the body or the whole body. Contamination can occur externally via the skin and mucous membranes and internally via inhalation and ingestion. Both external contamination and inhalation may occur either immediately or over the course of a few hours, first on-site and later in the near-field. Ingestion, on the other hand, occurs after radioactive material has entered the food chain and drinking water supplies, which generally takes much longer, both in the near-field and the far-field.

When only partial or whole-body radiation takes place, no first-aid measures are necessary, and health care workers run no risk of exposure or contamination. For evaluation purposes, it is important to discover whether a patient suffers from nausea and vomiting and how soon these symptoms occur. Since these symptoms can have other causes-psychological ones, for example-further evaluation will be necessary, which should usually take place in a hospital. For victims who develop neurological complaints either immediately or in the course of a few hours, the prognosis is poor. First-aid measures should be applied if these patients also have mechanical or thermal injuries. However, it is often not immediately apparent whether or not radiation exposure or contamination has occurred. Their occurence should be assumed barring proof to the contrary. Health care workers should therefore protect themselves appropriately by wearing facemasks, gloves, overshoes, and gowns. The patient should be wrapped in a sheet, not plastic film since it greatly disturbs the regulation of body temperature, and the stretcher

on-site

combined lesions: mechanical
thermal
nuclear: radiated
contaminated

near-field

nuclear lesions, contaminated only

far-field

depending on source strength, windforce and winddirection at most contamination

---

NB after days-months contamination
possible via water and food

Disorders of vital functions - respiration and circulation - take priority over all other injuries!
Whatever nuclear injuries are suffered these disorders must be treated first!

Therefore: Basic Life Support
& first
Advanced Life Support

should be wrapped in plastic film, thereby eliminating the necessity to clean it later. On-site triage and first-aid will be provided by staff employed at the accident location, assisted by medical experts specializing in radiation hygiene. A triage methodology, like the one for traumatic lesions, is not available for nuclear lesions proper. Therefore, victims with combined lesions should be selected primarily according to the triage methodology for the traumatic lesion sustained. On-site victims, who will usually be suffering from combinations of injuries, can be transported to neighbouring hospitals by ambulance. The first-aid departments of these hospitals must take extra space available to receive these victims, who may be contaminated. Health care workers should protect themselves appropriately in these situations.

Medical apparatus and any other equipment present in an area reserved for nuclear accident victims must be covered with plastic film. Any spread of contamination, including internal contamination. must be avoided. The clothing and bedclothes of victims and health care workers must be collected and held in safe keeping. Actual injuries must be treated first, by means of debridement, copious irrigation with sterile water, and the removal of foreign bodies. Irrigation fluid and foreign bodies must be kept and examined for radioactivity. Wounds should be closed only once it is established that no radioactivity remains. When wounds have been treated, the patient should be thoroughly washed with regular tap water that can be discharged in the usual way. Then other injuries such as fractures can be treated.

Those few victims suffering exclusively from internal contamination, such as those exclusively exposed to radiation, pose no risk to health care workers. In case of internal contamination, specimens of excreta (urine, feces, sputum, and vomit) should be kept and examined for radioactivity. Further medical examination will yield an estimate of the radiation absorbed, so that priorities for further treatment can be determined in consultation with other hospital departments. The amount of radiation absorbed is an estimate obtained from the actual radiation levels of the environment, clinical signs and symptoms (clinical dosimetry) and clinical measurement (biological dosimitry). Hospitals without access to nuclear accident expertise should call on any national organization dealing with individual radiation cases to provide them with a medical assistance team, or "N (for Nuclear) team". These teams consist of a medical and nursing specialist, a physics radiation expert, and an administrator and provide advice and coordination aimed at ensuring the best possible treatment for all patients. The further evaluation and treatment of victims suffering from internal contamination are of such a specialized nature that they are not considered further here.

In summary, curative measures for on-site victims consist primarily of measures to save life and limb and other first-aid measures, irrespective of nuclear injuries. For those who have been exposed or contaminated in the near-field, curative measures consist of individual case evaluation and management in decontamination centers (see below) and hospitals, possibly involving N-team assistance.

Public information

workers on site
rescuers
public in general

before and during the event

NB the more education and training,
the more stressproof the individuals
and the less panic and chaos.

Sheltering

max	open air	0
exposure		reduction of radiation
	ground level of brickhouse room without window and door	
0	cellar of a concrete building with a ventilation filter	max

---

covering mouth and nose
with a wet facemask or cloth

PREVENTIVE MEASURES

Preventive measures include the following: public information, sheltering, iodine prophylaxis, evacuation, and decontamination. These measures are intended for the action zone and should be taken on the basis of the intervention levels discussed above in order to protect the population from unnecessary exposure to ionizing radiation in the event of a nuclear accident.

Public Information

As for information aimed at the general public, government authorities must take the necessary action, especially with respect to population groups living near category A locations. A recent study among people living near a nuclear power station confirmed this view; it is concluded that the better local people were informed about the chances of a nuclear accident and the measures to be taken in such an event, the less anxious they were. This is a conclusion that must be taken seriously in the context of general information on disaster relief.

Sheltering

The extent to which a shelter can protect potential victims from exposure to ionizing radiation depends on its location and type. Sheltering in the cellar of a concrete building with a ventilation filter can eliminate exposure almost entirely. Exposure is at a maximum level in the open air. Between these two extremes, there is a wide range of possibilities.

Exposure is markedly reduced by sheltering in a room without windows or doors, or on the ground level of a brick house in which the doors and windows have been taped and cracks covered with moist rags. If such precautions are taken, exposure will generally be so low to be regarded as harmless. Even in less solid constructions, such as wooden houses, exposure-and especially inhalation-can be reduced by covering the mouth and nose with a wet facemask or cloth. Such measures can significantly reduce exposure to radioactive dust particles and water droplets.

Iodine Prophylaxis

Nuclear accidents, especially those in nuclear power stations, can cause a wide range of radioactive isotopes to be discharged into the atmosphere. Radioactive iodine is often an important component of these. Inhalation and absorption in the bloodstream cause this isotope to be resorbed selectively by the thyroid gland, which then becomes exposed to large concentrations of radioactivity. This greatly increases the risk of thyroid carcinoma developing over a 10- to 30-year

Iodine prophylaxis

- prevents thyroid carcinoma
- administration before or during the discharge of radioactivity
- e.g. Kj tablets of 170 mg. each;
  1 tablet each day for 3 days
- contraindicated: pregnancy < 3 months
  thyroid pathology
  iodine allergy
- children 1/2 dosage
- predistribution in near-field
- normal distribution in far-field, if necessary

evacuation

- public information before and during the event
- arrangement for sick and old people
- medical aspects concern preventive-hygienic measures only

period, leading to a rise in both morbidity and mortality. Anyone who ingests, stable iodine, preferably before or during the discharge, can eliminate or reduce the risk of thyroid carcinoma, since the iodine saturates the thyroid gland and prevents uptake of the radioactive isotopes. The radioactive iodine will be eliminated in the normal way via the kidneys, as will most other inhaled radioactive isotopes. Stable iodine, which can be ingested as either iodide or iodate, protects only the thyroid gland. Caution is advisable in administering iodine to children, pregnant women, persons with an abnormal thyroid gland, and persons with an allergy to iodine. Following Chernobyl, large sections of the populations of some East European countries and the former Soviet Union were given iodine without any noticeable adverse effects. The Dutch government has stored 15 million strips of three 170-mg potassium iodate tablets at reach of 22 different locations around the country for use in case of a nuclear accident within the Netherlands or in a neighbouring country. However, the distribution of tablets (1 tablet for adults and 1/2 tablet for children per day for 3 days) takes time, which is affordable in the far-field where distribution can take place before the radioactive cloud takes effect. But in the near-field, this time is insufficient. For this reason, potassium iodate must be immediately available to the entire population in the near-field, or more specifically in the action zone, and this can only be achieved by means of predistribution.

Evacuation

In view of the absence of public information on nuclear accidents like in the Netherlands, any organized evacuation of the population from an action zone would be impossible at the present time. If an acciedent were to occur, everyone living near the powerstation would pack their bags, jump in their cars, and head east, since the west is bounded by the sea and the prevailing winds blow from the southwest. Given the already crowded state of roads, this would inevitably lead to chaos, possibly resulting in additional death and injuries. The radioactive cloud would likely drift eastward an could cause further casualties from fallout over stalled traffic.

Since nuclear accidents are unpredictable, organized evacuation of the population from an action zone can take place efficiently only if preceded by an advance public information campaign. Experience with evacuations in other countries has shown that chaos can be avoided only through discipline and that discipline is only attainable bij means of effective public information. Medical problems of evacuation include the supervision of the sick and the aged, preventive medical measures in the reception centers, and care for them on their return journey. Additional details on these issues are beyond the scope of this chapter.

Decontamination

- in decontamination centre (by the fire bigrade)
- in the A &E depts of surrounding hospitals
- wounded (except the T1) should be washed
- non-wounded should shower
- wounds should be rinsed until radioactivity has disappeared and then closed
- the water used in this process can safely be discharged into the regular sewage system
- contaminated clothes should be collected separately
- decontaminated non-wounded casualties should be checked by general practioners
- persistent contaminated casualties to hospital
- *protection of health care workers*

Decontamination

Decontamination is a preventive measure for which fire department personnel will be responsible. Firefighters will be assigned to decontaminate people, animals, and material from the action zone who have been contaminated with radioactive material released by a nuclear accident.

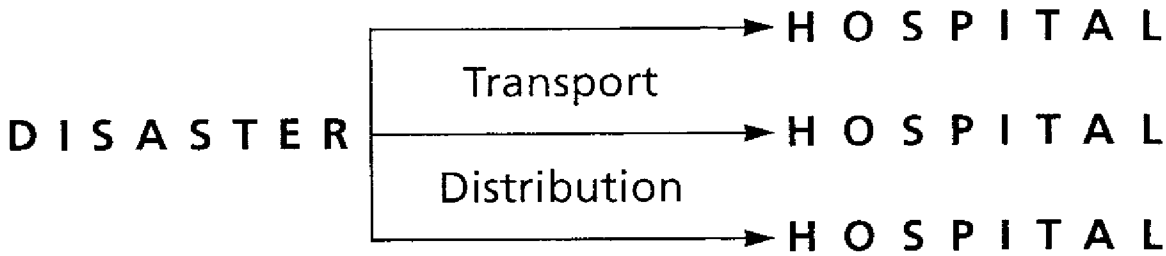
If the victims are evacuees, with or without domestic pets, they will first be received in decontamination centers outside the action zone, where they will be examined for internal or external contamination. Individual case evaluation, possibly based on random sampling in certain parts of the action zone-buildings, streets and blocks, for example-can help provide a picture of who is likely to have been contaminated in which part of the action zone. Persons belonging to high-risk groups will be decontaminated by showering and washing thoroughly with soap and water, after which they will be further screened to determine whether they have been sufficiently decontaminated. The water used in this process can safely be discharged into the regular sewage system. Patients suffering from persistently high levels of contamination will be sent to the hospital for further evaluation and examination.

Those with obvious injuries should of course be sent straight to the hospital without initially going through a decontamination center. Actions to save life and limb should always take priority over the treatment of nuclear injuries. The N-team can give logistical and evaluative assistance in the decontamination centers and hospitals. Health care workers in decontamination centers must wear adequate protective clothing. They should also guard against spending too much time on patients with nausea and vomiting who cannot be proven to be suffering from contamination. Vomiting can result from a prevailing fear of radiation as well as from contamination itself. After decontamination, victims can go to reception centers or, more commonly, to friends and relatives.

For the population in the action zone, on-site preventive measures will include sheltering, iodine prophylaxis, evacuation, and decontamination. Iodine prophylaxis will only be of use if predistribution has taken place. Sheltering should be the first measure, since the evacuation of a panicked population will cause chaos. The most logical order for preventive measures in the action zone would seem to be sheltering and predistributed iodine prophylaxis. After the radioactive cloud has blown over-or if there is enough time for a disciplined evacuation-victims may be evacuated via decontamination centers to reception centers, or directly to reception centers. In the far-field, the most appropriate measures would seem to be sheltering and iodine prophylaxis by means of a normal distribution system. However, if these preventive measures are to be implemented properly and in a disciplined manner, a large-scale public information campaign will need to be instituted.

ASSESSMENT OF MEDICAL DISASTER PREPAREDNESS*

* ADAPTED FROM AN ARTICLE IN THE JOURNAL OF PREHOSPITAL AND DISASTER MEDICINE (1997)



Medical rescue capacity (MRC)	**Medical transport capacity (MTC)**	**Hospital treatment capacity (HTC)**
Methods	Distribution plan	Disaster procedure
Personnel	Personnel	Personnel
Supplies	Ambulances	Supplies
Terrain and weather	Terrain and weather	Accomodation

In an earlier paper an attempt was made to calculate the so called disaster preparedness (dp) in the chain of medical care. Since the capacities in this chain are not only determined by the methods used, but also by personnel and the material to be utilized, the latter aspects should be considered as well.
Personnel and material should therefore also be incorporated in the medical assessment of disaster preparedness.
A more elaborated methodology will be described in the following.

Methodology

The medical organization for disasters can be divided into three more or less closed organizational systems:

* the medical organization at the site;
* the transportation and distribution of victims to and among neighbouring hospitals;
* the disaster procedures for the hospital themselves.

Along this chain of progressive medical care from the disaster site to the hospital bed, the victim is medically handled and treated. This is not only true for the Dutch situation, but is valid also for any calamity, whether a disaster or an accident, as long as there are victims who have to be treated medically.
Each of the three systems has its capacities:

* the medical rescue capacity (MRC), which could be defined as the number of victims receiving basic and advanced life support at the disaster site per hour. In earlier studies and during exercises it was found that a mobile medical team consisting of a surgeon, an anaesthesiologist and two nursing staff can provide this life support for about 8 seriously and moderately wounded (triage 1 and triage 2) casualties who have to be hospitalized. Well-trained general practioners and paramedics can probably handle the same number of casualties, providing they work as a team or at least in pairs.
* the medical transport capacity (MTC) is defined as the number of victims that could be transported per hour to neighbouring hospitals during the transportation and distribution phase. It is assumed that each ambulance has accomodation for two casualties. Moreover, this capacity is related to the number of ready-to-go ambulances and the average distance within the region where the ambulances are operating. From these figures the MTC could be estimated, for which a formula has been introduced.

$$MRC \approx MTC \approx HTC$$

$$\downarrow \quad \downarrow \quad \downarrow$$

personnel

material

methods

The lowest capacity in the chain will determine the capacity of the whole chain!

* the hospital treatment capacity (HTC) is defined as the number of victims who could be treated per hour in the hospitals. In case of casualties requiring surgery, the HTC is mainly dependent upon the number of surgeons, anaesthesiologists, nursing staff, operating room and intensive care facilities. Usually, these numbers are related to the number of hospital beds, and as a rule the HTC is considered to be 3%, i.e., 3 casualties per 100 beds per hour. This percentage is obtained from a large number of exercises and is valid for The Netherlands.

  For detailed studies of MRC, MTC and HTC see apropriate chapters.

To avoid stagnation in the chain of progressive medical care, synchronization of MRC, MTC, and HTC is imperative, which implies that these capacities should be equal to one another. One could have a situation with a large HTC but a small MTC, then the small MTC is determining the proper functioning of progressive medical care. Thus, the lowest capacity determines the capacity of the whole chain.

Personnel	
no personnel available	1
personnel being appointed	2
personnel available	3
personnel available and trained (certified)	4
personnel available, regular drills and upgrading	5
Materials	
no materials available	1
materials being purchased	2
materials available	3
materials available and tested	4
materials available, regular drills and upgrading	5
Methods	
no plan available	1
plan in preparation	2
plan available	3
plan available and tested	4
plan available, regular drills and upgrading	5

The grading of personnel, materials and methods.

---

grade	capacity
1	20%
2	40%
3	60%
4	80%
5	100%

Grading correlated to capacity.

The capacities are determined by plans and procedures, which in turn are based on the availability of personnel and materials.
What should be considered are therefore personnel, materials utilized and methods used.
Personnel is defined as doctors, nurses and paramedics who have their duties in the chain of medical care in an organized way, e.g. members of trauma teams, Red Cross personnel, ambulance crew or hospital personnel.
Material is defined as the essential equipment and apparatus necessary, qualitatively and quantitatively, in the chain of medical care for life and limbsaving treatment of triage 1 and triage 2 victims according to current medical standards.
A method is defined as a well thought-out and fixed way of acting in order to reach a certain goal, e.g. a triageprocedure for classifying victims in order to speed-up their transportation and final treatment, a treatmentprotocol for the optimal treatment of mechanically injured victims, a hospital disaster plan for the receipt of large numbers of injured, etc.
Personnel, materials and methods can be graded uniformly from 1 through 5.

In each phase in the chain of medical care personnel, material and methods should be considered.
By adding up the grades for personnel, materials and methods and dividing the sum of each of them by the different kind of medical rescueworkers, the various sorts of equipment and apparatus to be utilized and the number of plans available, a figure, ranging from 1 to 5 for personnel, material and methods can be obtained representing the quality of disaster preparedness for each of them.
So far, this grading only qualifies the determinants of the capacities.
Since the capacities are expressed in quantities e.g., number of patients per hour, the grading should be transformed into a quantification.
Considering the fact that the capacities are based on a 100% output, which means that personnel, materials and methods are available with regular drills and upgrading, the grading itself could be correlated as parts of this 100% performance.

An example may illustrate the methodology described.

Chain of medical care				
personnel	doctors 1	doctors 1	doctors 1	
	nurses 2	nurses 2	nurses 2	
	paramedics 3	paramedics 3	paramedics 3	
subtotal	(1 + 2 + 3) / 3	(1 + 2 + 3) / 3	(1 + 2 + 3) / 3	
material	ventilation 1	ventilation 1	ventilation 1	
	circulation 2	circulation 2	circulation 2	
	other material 3	other material 3	other material 3	
subtotal	(1 + 2 + 3) / 3	(1 + 2 + 3) / 3	(1 + 2 + 3) / 3	
methodes	attack plans 1	ambulance assistance 1	disaster procedures 1	
	triage 2	patient distribution 2	triage 2	
	treatment protocols 3	patient monitoring 3	simplification standardization 3	
subtotal	(1 + 2 + 3) / 3	(1 + 2 + 3) / 3	(1 + 2 + 3) / 3	
total				

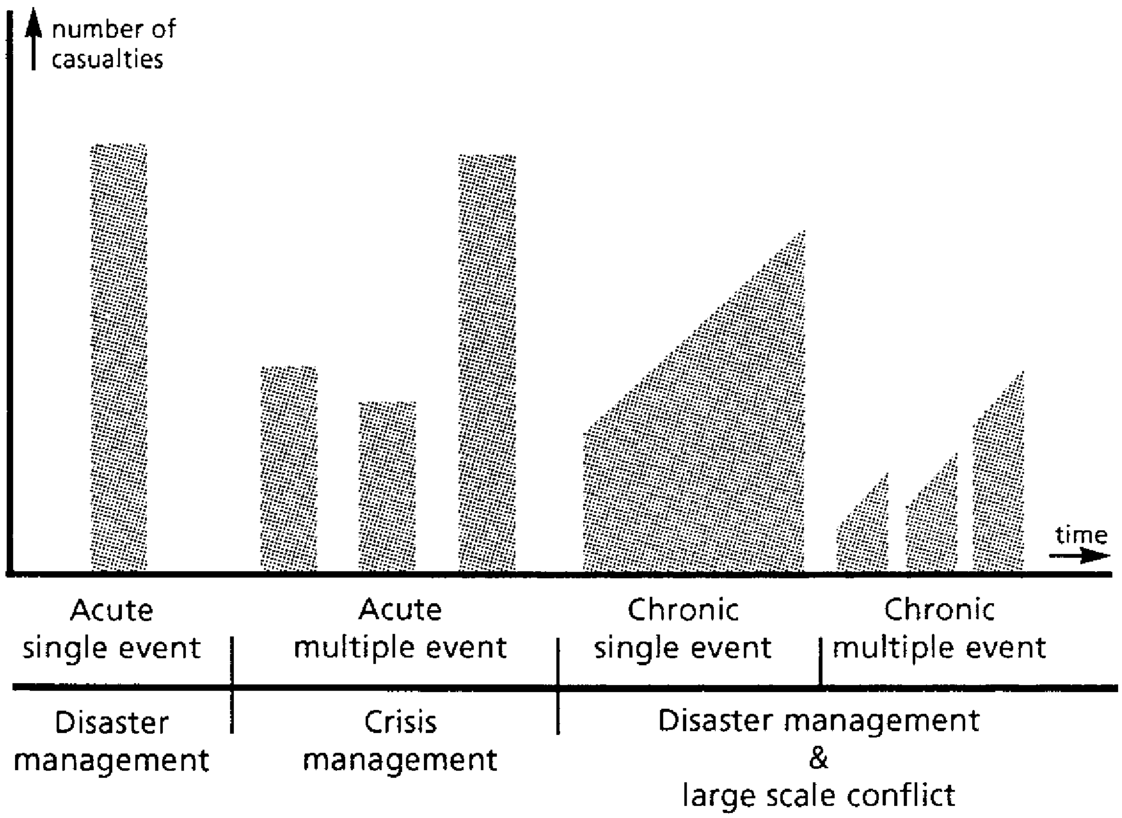
Gross estimate of the medical disaster preparedness in a distinct area.

A large international airport in the vicinity of a capital city will be considered, where a wide-body airplane may crash resulting in many deaths and severety wounded.
In this case the chain of medical care begins at the air-port, where men, working with certain materials and utilizing various protocols are dealing with the medical aspects of this major incident or disaster. Following the extrication of the victims from the wreckage by the fire-brigade the medical rescuers start their work, i.c. a sweeping triage for the triage 1 victims, life- and limbsaving measures, a second triage, first-aid for the triage 2 victims and preparing the victims for transportation.
The doctors, nurses and paramedics involved in the medical rescue activities at the site do not have a certificate in disaster medicine, nor are they well-trained in the use of their equipment and apparatus and in applying the available protocols. This implies a grading of 3 for each of them.
The materials for ventilation, circulation and for other essential purposes the medical rescuers are utilizing are not well tested, qualitatively as well as quantitatively, resulting in a grading of 3 for each of the catagories.
The methods to be applied are protocols: attack plans, triage and treatmentprocedures are available, however, not well tested, leading again to a grading of 3 for each of them. The subtotal for the disaster site, in this case the air-port is 3 + 3 + 3 divided by 3 is 3.
The second part in the chain of medical care is the transport and distribution phase of the ambulances.
Personnel involved in this phase are nurses and paramedics with some education and training in disaster medicine, however, they do not possess a seperate certificate in this field. The grading should therefore be considered again as 3 for each of them. The ambulances utilized in a mass casualty situation are the ones in use already in the daily routine. The material for ventilatory and circulatory support, as well as other relevant material is therefore available and tested. The grading is therefore 4 for each of them. The methods like ambulance assistance, patient-distribution and patientmonitoring for a mass casualty situation are available, but not properly tested, except for the latter, resulting in a grading of 3 for the first two methods and 4 for the latter, resulting in a grading of 3.3 for the methods. The second phase has a subtotal of 3 + 4 + 3.3 divided by 3 is 3.4.
The third part in the chain of medical care is the hospital phase. In the vicinity of this imaginary air-port six hospitals are located with a collective bedcapacity of around 2000 beds, resulting in a hospital treatment capacity of 60 triage 1 and 2 victims per hour provided they have a well trained and up dated hospital disaster procedure. Only the accident and emergency department will be considered. Personnel involved are doctors, nurses and paramedics, without education and training in disaster medicine. On the other hand they are well-trained for the single event and daily routine. The grading could thus be set as 4 for each of them.
The material in use for immediate ventilatory and circulatory support is of course also available, resulting in a grading of 4 for each. The methods, like the hospital disaster procedure, triage, and simplified and standardized treatment protocols are in preparation, yealding a grading of 2 for each of them. The subtotal for the third phase 4 + 4 + 2 divided by 3 is 3.3.
Since the grading determines the capacity and since the lowest capacity determines the capacity of the whole chain of medical care, the overall grading for this airport can be set at 3.

Various possibilities of mass casualty situations

Approach:
1) Top-down
2) Bottom-up

Based upon:
scenario's / industry, traffic
capacities / scaling



Discussion

In the past, managers were satisfied already having some equipment and apparatus ready to cope with disasters. Nowadays disaster managers realize that not only material is essential to solve the complicated medical aspects in a mass casualty situation, but also the personnel involved and methods to be utilized are of paramount importance.

The methodology described for the assessment of the medical disaster preparedness is a gross estimate since only major items were classified. One could imagine that a shortage of infusion needles in the chain of medical care may jeopardize the lifes of many victims, in which case sophisticated ambulances and well-trained doctors do not contribute much to improve overall mortality, morbidity and disability.

In this respect three main groups of materials were differentiated only: equipment for ventilatory and for circulatory support and other essential materials like stretchers, bandages and splints. It is possible, however, to differentiate into more than three items.

The same holds for the methods to be applied. Only three types of methods were mentioned, however, the treatment protocols themselves could also be differentiated into those for the treatment of mechanical lesions, chemical lesions and nuclear lesions. When this is done, the materials should be differentiated in the same way.

Dependant on the number of material items, methods or type of personnel the subtotals and thus the overall total will gain reliability in this respect. The more differentation, the better results and thus a more reliable figure for disaster preparedness.

Since the grading determines the capacity and since the lowest capacity in the chain of medical care determines the capacity of the whole chain, the disaster preparedness of a certain object at risk (air-port, harbour)or any other region is determined by the lowest grading in this chain.

By analysing the medical disaster preparedness (MDP) in the way described, not only a figure could be obtained, but also the weak points in the chain of medical care could be traced immediately.

Various mass casualty situations are possible, which is shown in the illustration. The assessment of the medical disaster preparedness is either top-down by analysing imaginary scenarios, or bottumup by analysing the available capacity in the chain of medical care.

GLOSSARY OF NEW CONCEPTS IN DISASTER MEDICINE

(additional to Gunn's Multilingual Dictionary of Disaster Medicine)

M. Debacker
B. Domres
J. de Boer

Each discipline needs its language. Only then it will be feasable to communicate in a scientific way.

It was William Gunn who recognized this basic thought for which he created the first Multilingual Dictionary of Disaster Medicine in the late eighties. This expertise, however, was focussed mainly on remote and naturally-occurring disasters and not so much on domestic man-made ones. Besides, disaster medicine, a young branche on the old tree of medicine, is growing fast and is developing itself as a science.

New concepts in disaster medicine are being introduced and that is why Gunn's dictionary needs to be supplemented with concepts, which could be found in the literature (see references).

For the same reasons, the European Academy of Disaster Medicine (EURADEM) was founded in 1996. According to its statutes the main aim is to safeguard the academic level of disaster medicine as a specialism in Medicine. One way to achieve this is by issueing a complete glossary of concepts in disaster medicine periodically.

Of course, this is not definite and needs periodic updates. The issueing of this glossary stimulates teachers at the University level to lecture disaster medicine in such a way that at least basic concepts are defined uniformely.

Again this glossary is supplementary to Gunn's dictionary. In the future both efforts should be combined.

GLOSSARY OF NEW CONCEPTS IN DISASTER MEDICINE

Advanced life support
ALARA
Alarm procedure
Ambulance support

Basic life support

Casualty clearing station
Casualty
Central holding area
Chain of medical care
Chemical lesions
Community profile
Contamination
Crash team

Decontamination
Definition, classification and scoring of disaster
Disaster Medicine
Disaster Severity Scale
Disaster site

Epidemiology of disaster

Far field
Filter area
First acts
First-aid post
Forward control point
Friedrich's time

Golden hour

Hospital Treatment Capacity

Hygienic measures

Identification of dead
Intervention levels
Iodine prophylaxis

Maesure zone
Mass casualty
Mechanical lesions
Medical Rescue Capacity
Medical Severity Index
Medical Transport Capacity
Medical Disaster Preparedness
Medical coordination
Mobile medical teams

Near field
Nuclear lesions

Plans, procedures and protocols
Posttraumatic stress syndrome
Prevention
- primary
- secondary
- tertiary

Sheltering
Simplification
Standardisation
Sweeping triage

Victim
Victim distribution

GLOSSARY OF NEW CONCEPTS IN DISASTER MEDICINE

Advanced life support
Those invasive measures as to preserve life of ABC-instable patients like intubation and ventilation, infundation and thoracic drainage.

ALARA
As Low As Reasonably Achievable; concept utilized in relation to intervention levels following the release of dangerous chemical or nuclear materials.

Alarm procedure
Repressive disaster management is preceeded by alerting every party concerned. Various optical and acoustical means of alarm are possible: flags, lights, sirenes, radio and telephone.

Ambulance support
When disaster strikes a certain (ambulance) region, ambulance support is needed from surrounding regions according to a preplanned scheme.

Basic life support
Those non-invasive measures as to preserve life of ABC-instable patients like elimination of airway obstruction, cardio-pulmonary resuscitation, hemorrhage control, woundcare and immobilisation of fractures.

Casualty clearing station
Collecting point for T1 en T2 victims in the immediate vicinity of the disaster site where further triage and basic and advanced life support can be provided.

Casualty
Any person suffering physical and/or psychological damage by outside violence leading to either death, injuries or material losses only.

Central holding area
An ambulance assembly location in the filter area from where ambulances either leave to pick-up patients from the casualty clearing station or to leave for one of the neighbouring hospitals according to a victim distribution plan.

Chain of medical care

The chain of medical care from the disaster site to the hospital bed, along which the patient is medically handled and treated, can be devided into 3 phases: the medical organisation at te site, the distribution of patients among neighbouring hospitals and the organisation in the hospitals.

Chemical lesions

Body lesions caused by chemical substances either through external (skin and mucous membranes) or internal (inhalation and ingestion) contamination or both leading to a variety of reactions from skin irritation and ventilatory problems to systemic effects and even death.

Community profile

Caracteristics of the local environment prone to a chemical or nuclear accident: population density, age distribution, roads, railways, waterways, types of dwellings and buildings and the relief agencies locally available.

Contamination

Accidental release of hazardous chemical or nuclear materials leads to pollution of the environment in which man could be contaminated by these materials, either externally (skin and mucous membranes) or internally (by inhalation or ingestion) or both.

Crash team

Team comprising a doctor and a nurse specialized in advanced trauma life support and meant for stabelising seriously wounded victims.

Decontamination

The removal of hazardous chemical or nuclear substances from the skin and/or mucous membranes by showering or washing with water, or out of wounds by rinsing with sterile solutions.

Definition, Classification and Scoring of Disaster
From a medical point of view a disaster needs only two criteria: victims and a discrepancy between the number and treatment capacity. Disasters can then be classified utilizing various parameters; man-made versus God-made, the radius of the disaster site, the number of dead, the number of wounded, the avarage severity of the injuries sustained, the impacttime and the rescuetime.
By attributing 0, 1 or 2 to each of them, increasing with intensity, number or time a scale can be produced varying between 0 and 13, which is called the Disaster Severity Scale.

Disaster Medicine
The combination of medical and medico-organisational measures undertaken in case of disaster covering the entire range of medical care from the scene of the disaster to the hospital bed.

Disaster Severity Scale
See Definition, Classification and Scoring of Disaster.

Disaster site
Area where the immediate impact of the disaster took place. The first duty of the Police is to seal down this area by an inner cordon. Outside this cordon a second one can be laid: the outer cordon. The area in between both cordons is then called the filter area, through which at one or two points the disaster site can be reached by rescuers.

Epidemiology of disaster
Only with a uniform and standard definition, classification and scoring system for (the medical aspects of) disasters is epidemiologic research feasible.

Far-field
Following a nuclear accident on-site, e.g. a nuclear plant, the immediate vicinity is called near-field with a diameter varying between 2 and 20 kilometers, depending on the source strength. The area outside the near-field is called the far-field, where effects are still noticeble after an accident.

Filter area
The area between the inner and outer cordon around the disaster site. See disaster site.

First acts

The first acts of doctors and nurses at the disaster site are Anticipation, Control, Triage, Treatment and Transport (ACTTT).

First-aid post

Collecting point for T3 victims in the immediate vicinity of the disaster site, however separate from the casualty clearing station, as to divide the T1 and T2 flow of patients from the T3 one.

Forward control point

The point next to the disaster site where the first ambulances to arrive are those to function as a command, coordination and communication post.

Friedrich's time

4-6 hours following sustainment of mechanical injuries T2 victims may become ABC unstable when untreated. It is therefore important to provide first-aid measures within this period of time.

Golden hour

ABC-unstable victims (T1) should be stabilised as soon as possible, at least within one hour following injury, otherwise they will die.

Hospital Treatment Capapcity

The number of T1 and T2 victims, which can be treated in a hospital per hour, according to current medical standards.

Hygienic measures

Those measures as to prevent diseases following a major disaster, because the infrastructure of the stricken area is non- or malfunctioning.

Identification of dead

Disasters with "unknown" dead necessitate identification of the bodies or their remains. This is important for the bereaved, not only from an emotional point of view, but also for judicial and insurance purposes. Various medical disciplines are involved in matching ante-and post-mortem findings.

Intervention levels
Levels of radiation or concentrations of chemicals in the environment. These levels determine the measures to be taken in the measure zone and can be regarded as aids to decision-making.

Iodine prophylaxes
Radioactive iodine is often an important component of radioactive isotopes to be discharged into the atmosphere after a nuclear accident. Stable iodine prevents the absorption of radioactive iodine in the thyroid gland provided it is administered beforehand.

Maesure zone
The zone where measures are to be taken in case of nuclear or chemical accidents. These zones are determined by the community profile and the source strenght.

Mass casualty
The definition of disaster implies a discrepancy between number of victims and its treatment capacity. This does not necessarily means a mass casualty situation, in which case the number of victims is overwhelming.

Mechanical lesions
Mechanical impact on the human body creates injuries like wounds, lacerations, fractures, bleedings (internal and external) and concussions. Mechanical lesions also include burns.

Medical Rescue Capacity
The number of victims which could be rescued and stabilised at the disaster site per hour by doctors, nurses and paramedics.

Medical Severity Index
The ratio between the number of victims times the average severity of the injuries sustained and the treatment capacity in the chain of medical care. When this ratio is larger than 1 the event can be considered a disaster.

Medical transport capacity
The number of victims which could be transported to and distributed between the hospitals surrounding the disaster site, per hour.

Medical disaster preparedness
The medical preparedness in the chain of medical care is determined by personnel, materials and methods. With the aid of this basic concept medical disaster preparedness can be expressed in a figure ranging from 1 to 5.

Medical coordination
In the chain of medical care coordination between its phases and in each phase between doctors, nurses and paramedics, is of paramount importance. Simplification and standardisation of materials and methods utilised is therefore a prerequisite.

Mobile medical teams
In stead of bringing the patient to the hospital, the hospital is coming to the patient for which mobile medical teams are created in order to stabilise the patient on the spot and this could shorten the treatment delay.

Near field
See far field. Concept used after a nuclear accident.

Nuclear lesions
Body lesions caused by external exposure to radiation and internal of external contamination with radioactive material. Radiation exposure can effect part of the body or the whole body. External contamination effects skin and mucous membranes, while internal contamination leads to systemic effects or effects on specific organs (e.g. the thyroid).

Plans, procedures and protocols
A well though-out and fixed way of acting in order to reach a certain goal and written down as plans, procedures and protocols.

Posttraumatic stress syndrome
Following a period of intense stress (like in disaster) a person may encounter psychic disorders on the short or long term varying among other things from auxiety, insomnia, feelings of guilt, irritability and concentration problems.

Prevention
Primary prevention of disaster is possible through technical, organisational and judicial means. Secondary prevention implies the optimal management of disaster itself.

Tertiary prevention combats the complications of disaster. The better secondary prevention, the less tertiary prevention is needed.

Sheltering
The extent to which a shelter can protect potential victims from exposure to ionizing radiation and contamination with radioactive material depends on its location and type. Exposure is at a maximum level in the open air and at a minimum in a cellar of a concrete building with a ventilation filter

Simplification
Simplification of medical procedures saves time so that more attention can be paid to the seriously wounded victims, e.g. large wounds should be disinfected and covered and in a later stage closed with plastic and reconstructive surgery.

Standardisation
Standardisation of medical procedures, like the administration of drugs, antibiotics, analgesics and anticoagulants in the chain of medical care avoids errors, simplifies the transfer of medical information in this chain and is more economic.

Sweeping triage
The first triage at the disaster site in order to locate the most seriously wounded T1 victims.

Victim
Casualty with sustained lesions of mechanical, chemical or nuclear nature or combinations.

Victim distribution
Victims should be transported to and distributed among neighbouring hospitals according to their hospital treatment capacity, while the nearest hospital should be avoided, since walking T3 victims will overcrowd this one. For this a preplanned victim distribution plan is required.

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