TRIAGE AND MEDICAL MANAGEMENT OF CRITICALITY ACCIDENT VICTIMS

L. Lebaron-Jacobs[1], D. Cavadore[2], A. Flüry-Hérard[1], G. Lemaire[1], R. Médioni[3], P. Voisin[3], M Fatome[4], C. Challeton-De Vathaire[3], C. Riasse[1], E. Rongier[3], M. Gonin[5], J-P. Le Goff[1], R. Fottorino[1], A Miele[1]

[1] Commissariat à l'Energie Atomique/Cadarache – 13108 Saint Paul Lez Durance Cedex, France
[2] COGEMA/Marcoule – 30207 Bagnols sur Cèze Cedex, France
[3] Institut de Radioprotection et de Sûreté Nucléaire, 92265 Fontenay aux Roses Cedex, France
[4] Centre de Recherche du Service de Santé des Armées, 38702 La Tronche, France
[5] Electricité de France 22-28, Rue Joubert, 75009 Paris, France

INTRODUCTION

The criticality accident is the result of an uncontrolled chain fission reaction initiated when the quantities of nuclear materials (uranium or plutonium) present accidentally exceed a given limit called the "critical mass". As soon as the critical state is exceeded, the chain reaction increases exponentially. The result is a fast increase in the number of fission events which occur within the fissile medium. This phenomenon results in a release of energy mainly in the form of heat, accompanied by the intense emission of neutron and gamma radiation and the release of fission gases (Barbry, 1983).

Criticality accidents are significant because of the loss of control of special nuclear material and the resultant radiation doses to personnel and release of radioactive material to the workplace and the environment. Recent criticality accidents such as Sarov (1997) or Tokaï-Mura (1999) have demonstrated the importance of adequate preparation for dealing with such emergencies.

It is important to assess rapidly the absorbed dose to carry out a correct triage between the exposed and the involved persons. However the whole-body dose assessment is essential for the triage but not sufficient due to the heterogeneity of exposure: the evaluation of the seriousness is indispensable to the medical management.

A group of physicians, biologists and physicists from occupational health medicine services and clinical biochemistry laboratories of French sites with nuclear installations has devised easily accessible comment forms which provide the elements of medical management in order to deal criticality accident victims.

Following a radiological criticality accident, the exposure is heterogeneous given the two radiation components (neutron and gamma). Consequently the maximum absorbed dose is located at the point of input of the incident beam, and decreases according to the depth.

The Acute Radiation Syndrome (ARS) is the combination of syndromes that occur after whole-body irradiation. These develop in successive stages over periods ranging from hours to several days. They consist of all the clinical and laboratory signs related to the morphological lesions or functional impairment of the target organs exposed to ionizing

radiation. The various tissues of the body exhibit different degrees of sensitivity to ionizing radiation. This variability in radiation sensitivity explains the signs and the symptoms that occur in three successive stages: an initial syndrome that develops in the first few hours after exposure, a relatively asymptomatic remission phase and a patent phase at clinical and laboratory levels. Death or recovery occurs within 8 weeks of exposure (Anno, 1989).

Triage carried out during the initial syndrome and assessment of radiation exposure seriousness are essential to the medical management of criticality accident victims and to decisions which orientate the patient to an hospital or to a regular doctor.

DIAGNOSIS PHASE: TRIAGE

From the very start of victim management, a victim identification sheet must be drawn up. All relevant data must be written clearly on the sheet with the date, time and name of the person noting each particular piece of the data. The sheet must accompany the victim throughout the management period so as to ensure optimal transfer of information to the various health care teams.

First it is important to gather rapidly as much data as possible about the conditions of the accident; these data are essential to the assessment of the absorbed dose. Since the irradiation is heterogeneous, a physical reconstruction of the dose is indispensable to make up for the deficiencies of biological dosimetry.

The physical dosimetry following a criticality accident rests on:

- the interview with a precise description of the conditions of the accident (subject's position relative to the source, to fixed points and to other people present at the time of the accident…)
- the probable duration of radiation exposure and evacuation route (make a drawing)
- the collection of the available individual and surrounding dosimeters
- the collection of objects for dosimetry (matches, coins,…)
- and above all the measurement of body ^{24}Na activation to carry out an emergency triage (Swaja, 1987).

The irradiated victims are rapidly taken to the on-site occupational health medical service, where a clinical examination and anthropogammametry can be done. Biological samplings are carried out in emergency, following labeling of all the samplings and the documents indicating the time and possibly the location:

- Repeated blood samplings:
  - Blood Cell Counts, reticulocytes, platelets
  - Cytogenetics
  - HLA I and II , erythrocyte group
  - APTT, PT, fibrinogen, factors II, VII, X
  - Biochemical and enzymological tests
- integument (hair and nails) sampling for dosimetry (distribution of neutron dose) (Hankins, 1980)
- collection of excreta and samplings for radiotoxicology.

This first analysis of biological status has to be carried out within the three first hours following the accident.

On the other hand, the implicated victims (non irradiated) are taken to the health medicine service, where a clinical examination and an anthropogammametry are realized. Later they fill in the "post-accidental interview" comment form to estimate the victim's position relative to the source, the probable duration of radiation exposure and the distribution of dose.
In parallel the first measures of internal and external decontamination have to be carried out, and always within the context that the medical treatment of victims always takes precedence over any radiological treatment.

The hospitalization of the victims is decided in an emergency or is deferred on the basis of their clinical presentation together with biological and dosimetric status. The decision of hospitalization in an emergency is primarily based on:

- vision of a blue flash (Cerenkov effect), clinical signs as of hour 1, injuries
- rapid appearance of serious symptoms (neurological disorders, seizures, hyperthermia, vomiting, diarrhea, hemorrhage)
- result of ^{24}Na activation measure (dose>1 Gy).

PROGNOSIS PHASE: ASSESSMENT OF SERIOUSNESS

The initial syndrome develops in the first few hours after exposure and may last 24 hours. Since the symptoms characterizing the initial syndrome are non specific, it is essential to assess rapidly the seriousness in order to establish a later prognosis and to carry out a suitable medical management. Three parameters are indispensable in order to evaluate seriousness: clinical state, radiation exposure conditions and biological results.

The remission phase that follows the initial syndrome is relatively asymptomatic. It may last from few hours up to day 20 post exposure. This phase reflects the lag time between the initial radiation-induced cell lesions and their clinical expression, which depends on cell turnover in the affected organs. It should be noted that many biological parameters are disturbed during the remission phase. Monitoring these parameters over the classically silent period supply reliable prognosis information.

The acute radiation syndrome is classically divided into haematopoietic, gastrointestinal and neurovascular syndromes, but also includes cutaneous, pulmonary or oropharyngeal symptoms.
Apart from the emergency, the medical decisions are made from the results of this particular monitoring and the foreseeable evolution of the symptomatology based on the heterogeneity of the absorbed dose in the organism and the dosimetric assessments. Notably the massive cellular lysis of the overexposed areas may contribute to the failure of some organs such as myocardium, liver and kidneys.
Since the distribution of the absorbed dose is heterogeneous, the cell death and the inflammatory syndrome are not uniformly distributed in the organism. Consequently it is essential to take tissue samples to estimate the proportion of surviving and functional stem cells from bone marrow, gut and skin.
The seriousness depends on:

- the absorbed dose received:

        - at very high doses Central Nervous System incapacitation leads rapidly to death
        - for doses > 1 Gy, irradiation decreases cell turnover with a risk of infection and hemorrhages. The most marked consequences are observed in the following tissues:
            - hematopoietic bone marrow (the decrease in cell count may lead to aplasia)
            - cutaneous tissue (radiological burns)
            - gastrointestinal system (destruction of the mucosa)
        - for doses < 1 Gy, there are no clinical consequences
    - associated injury
    - topography of irradiated sites.

During this critical phase, the correlation between clinical, biological and dosimetric results contribute to the evaluation of prognosis and help the medical teams to provide the necessary adapted treatment.

Moreover the seriousness of radiation exposure is estimated, among other factors, from two specific tests:

- cytogenetics: on lymphocytes, the early chromosome aberration rate obeys a dose-effect relationship. It is possible to determine the whole-body absorbed dose and to evaluate the degree of heterogeneity of the irradiation
- neutron irradiation induces specific modifications of the EEG with fast wave spikes (benzodiazepine-like). These modifications obey a dose relationship enabling an estimation of first whole-body irradiation, and secondly the level of skull irradiation.

TREATMENT

Exposures with a high neutron component results in specific injuries which are difficult to handle.

The careful collection of the initial clinical, biological (hematological, biochemical, cytogenetic …assays) and dosimetric data and details of the accident history are of vital importance for both the general hospital and/or the specialized centers to enable the correct diagnosis, prognosis and treatment to be established.

1 – Exposed victims

Only those victims with combined injuries and/or severe initial syndrome will require treatment in the reception area of the on-site occupational medicine service. These victims will be then rapidly transferred to the hospital. Medical management of neutron overexposures, when the size of burns is important and when skin basal layer receives doses which result into necrosis, is very difficult. Moreover, in most cases of high mixed neutron/gamma irradiation death occurred because of multiple organ failure in relation to a systemic inflammatory response syndrome due to severe neutron overexposure.

The symptomatic treatment and the prevention of initial clinical symptoms have to be continued closely with the medical staff of the occupational health medicine service.

When the victims are hospitalized in a specialized hematological department, an assessment of residual hematopoiesis should to be carried out to show the degree of aplasia . This aplasia

is treated symptomatically (transfusion of irradiated blood products) and a strict prophylaxis of infection is required:

- selective decontamination of the digestive tract
- isolation with sterile food and drink
- antibiotic prophylaxis for the control of bacterial or fungi or viral infections

Severe exposure rapidly gives rise to symptoms of dehydration and malnutrition, particularly if associated with a gastrointestinal syndrome and/or extensive burns. Sterile oral nutrition is preferable (Mettler, 2001).
Vomiting can generally be effectively controlled with 5-HT3-receptor antagonists. Antidiarrheal drugs such as anticholinergic agents are effective in treating initial diarrhea during acute and sub-acute phases (Hunter, 1991).

2 – Implicated victims
The implicated victims are persons who have not presented with any clinical signs during the initial state and have received an absorbed dose less than 1 Gy. Consequently they have to consult their own regular doctor for an outpatient follow up (clinical and haematological at days 3 and 21).

CONCLUSION

The assessment of the absorbed dose and the medical management of a criticality accident are complex. However, certain actions are easy to design during a criticality accident and help to make up for insufficiencies:

- rapid estimation of the absorbed dose by the measure of whole body ^{24}Na activation to carry out an emergency triage
- follow up of the Blood Cell Count
- lecture of the individual and surrounding dosimeters
- measure of ^{32}P in the integument taken at various locations of the body
- cytogenetic analyses.

Moreover it is essential to optimize the help and assistance procedures between on-site occupational health medicine services and clinical biochemistry laboratories, and the coordination between CEA sites for dosimetric exploitation.

REFERENCES

- Barbry F., Fuel solution criticality accident studies with the SILENE reactor : phenomenology, consequences and simulated intervention, International seminar on criticality studies programs and needs. ICNC'83, Sept 1983, Dijon (France).

- Anno G.H. and al., Symptomatology of acute radiation effects in humans after exposure to doses of 0.5-30 Gy, health Physics, 1989, 56, 821-838.

- Swaja R.E. and R. Oyan, Uncertainties associated with using quick-sort techniques to estimate neutron doses following criticality accidents, Health Physics, 52, 65-68, 1987.

- Hankins D.E., Dosimetry of criticality accidents using activations of the blood and hair, Health Physics, 38, 529-541, 1980.

- Mettler F.A. Jr, L. G.L. Voelz, J.C. Nenot and I.A. Gusev, Criticality accidents, In : Medical management of radiation accidents, Second Edition I.A.Gusev, A.K. Guskova and F.A. Mettler Eds, CRC Press, Boca Raton, 173-194, 2001.

- Hunter A.E. and al., Granisetron, a selective 5-HT_3 receptor agonist, for the prevention of radiation induced emesis during total body irradiation, Bone Marrow Transplantation, 7, 439-441, 1991.