MEDICAL EXPERIENCE: CHERNOBYL AND OTHER ACCIDENTS

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Abstract

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A radiation accident can be defined as an involuntary relevant exposure of man to ionising radiation or radioactive material. Provided one of the ensuing criteria is met with at least one person involved in an excursion of ionising radiation and or radioactive material, the respective incident can be considered a radiation accident in accordance with ICRP, NCRP (US), and WHO :

- ≥0,25 Sv total body irradiation with lesions of the rapidly dividing tissues;
- ≥6 Sv cutaneous and local irradiation;
- ≥0,4 Sv local irradiation of other organ systems through external sources;
- incorporation equal to or in excess of more than half of the maximum permissible organ burden; and
- medical accidents meeting one of the above criteria.

Several actions have been taken to categorise radiation accidents in order to learn from previous accidents in terms of both managerial and medical experience. For this presentation three approaches will be discussed concerning their relevance to the individual treatment and risk management. This will be obtained by applying three classification schemes to all known radiation accidents:

1. classification with respect to the accident mechanism,
2. classification concerning the radiation injury, and
3. classification concerning the extent of the accident.

In a fourth chapter the efficacy of bone marrow transplantation will briefly be commented on based on the accumulated experience of about 400 radiation accidents world-wide.

2. CLASSIFICATION WITH RESPECT TO THE ACCIDENT MECHANISM

The classification by the accident mechanism is related to the names of C. C. Lushbaugh and S. Fry and others who originally devised that scheme for the Oak Ridge radiation accident registry. The accidents are analysed by physical criteria of their mechanism (Lushbaugh 1981, 1990).

When analysing the data concerning the mechanism, it becomes apparent that firstly there is no increase in the number of radiation accidents any longer. Secondly, the radiography accidents have declined sharply through means of technical improvement of the sources, whereas, the medical radiation accidents have increased. Thirdly, with the exception of Chernobyl criticality accidents have disappeared at all. This is also well in contrast to the statement of Mettler (Mettler 1990a, b) that most fatalities were results of industrial radiation accidents. Instead, the medical misadventures have accounted for most of the fatalities.

3. CLASSIFICATION CONCERNING THE RADIATION INJURY

From a medical viewpoint it is seemingly quite natural to classify accidents by the consecutive injury both concerning the individual and the potential harm to larger parts of the personnel and or residents living close to accident sites (Fliedner 1982, Kirchhoff 1980, Rabin 1986). By the type of related injuries four accident classes can be identified:

Table 1: The Different Accident Mechanisms as Identified in the Oak Ridge Registry and Examples

Accident Mechanism	Example
• Criticality	
critical geometry	Oak Ridge Y-12, 16.06.1958,
reactor accidents	Chernobyl, 26.04.1986,
radiochemical reactions	Los Alamos, 30.12.1958;
• Radiation Devices	
sealed radiation sources	Sor-Van, 3.9.1990; Cottbus, 1983/1984, 61 involved, approx. 30 deaths
x-ray devices	England 1961, 11 involved,
radar generators	Lockport 1960,
accelerators	Yakima, Wa. 1987 2 deaths; Hamburg, 1972, 9 involved
• Radioisotopes	
Tritium	Switzerland, 1957
transuranics	Oak Ridge X-10,
radioactive fission products	Eniwetok,
diagnosis and therapy	Houston, Tx. 1980, 7 deaths by ^{90}Y
others	Gore, Okl. UF_6 with 110 involved

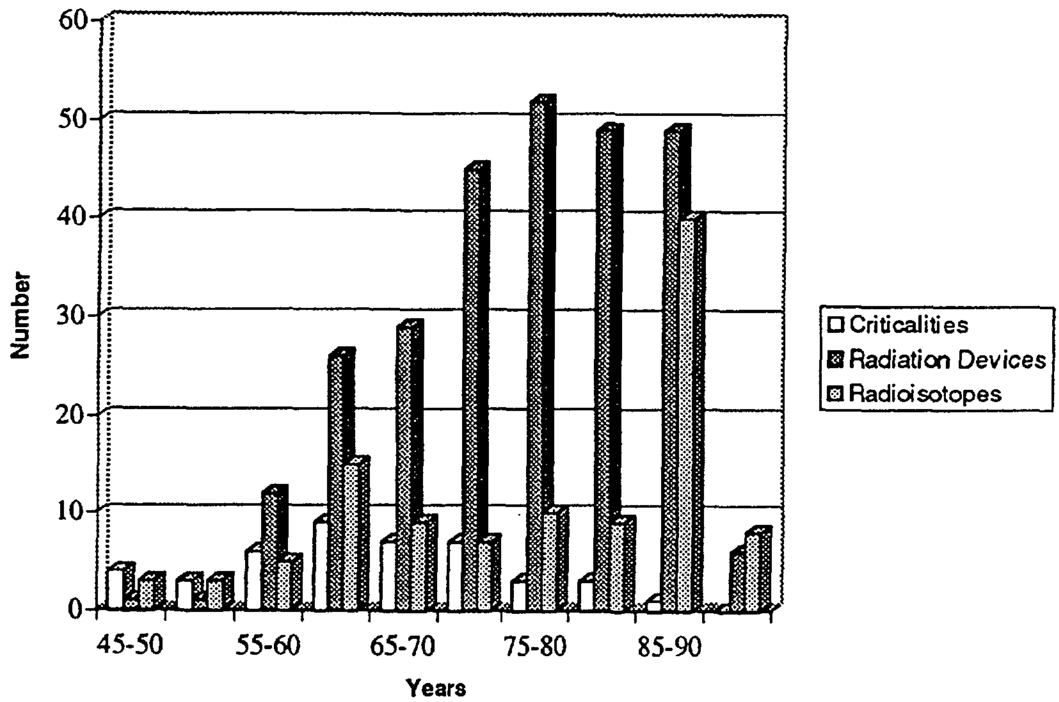

Figure 1: Comparing Radiation Accidents in Terms of Different Mechanisms

- Penetrating total or partial body exposure — the severity is closely related to the deposition of energy, the part of the human body exposed, and the duration of the exposure. Usually, a victim of this type of accident will pose no threat to the public. The managerial problems are solely related to the handling of the acute radiation syndrome [Nesvidge, Belarus, 1991].
- External contamination with radionuclides — again, the severity is closely related to the deposition of energy. However, the effects will be dependent on amount, extent of body surface, duration of exposure, type of radiation emitted (LET, penetration), and the contaminating isotope. Main managerial issues with this type of accident are to

avoid ingestion and absorption on the side of the individual, and in terms of public health aspects to avoid further contamination through the victim(s) of areas beforehand unaffected [Switzerland 1957].

- Internal contamination with radionuclides — the severity is also related to the local energy deposition, but is dependent from the radio sensitivity of the neighbouring tissues and both the chemical and physical properties of the intruding isotopes. With internal contamination especially the aspects of decorporation will be of medical concern. Questions to be addressed are in this case the biological half life and the toxicity of the respective compound. [Houston, Tx. 90Y — accident (Lincoln 1976)].
- Combinations of the above — sometimes even complicated by other traumas, e.g. burn or fractures. Physical trauma will substantially reduce the chance for survival [Chernobyl].

4. CLASSIFICATION CONCERNING THE EXTENT OF THE ACCIDENT

Thirdly, radiation accidents can be classified by their size. This type of categorisation stresses the managerial problem of the handling of mass casualties. Considerations concerning the size of the accident are especially relevant when trying to learn lessons from previous accidents in terms of preventing catastrophes from occurring or at least to have at hand some procedures to follow if a large scale accident happens.

After intense brain storming with Prof. Jammet it has been decided that three categories can be identified concerning the accident size (Densow 1993):

- small accidents, with less than ten persons involved, e.g., radiation devices,
- medium size accidents , with more or equal than 10 up to 100 persons involved, e.g., medical accidents, and
- large scale accidents involving at least 100 people.

Whereas, category 1 in the Federal Republic will require only the emergency system of the workmen's compensation board to become activated, the second level will demand countermeasures at least on the part of the state government, if not the federal government. Coming to the third with hundreds of people involved it is hardly imaginable that the situation can be handled by one individual member of the EU states. It is almost certain that the Commission of the European Union will have to react in order to assist the member country befallen by disaster (BMI 1986).

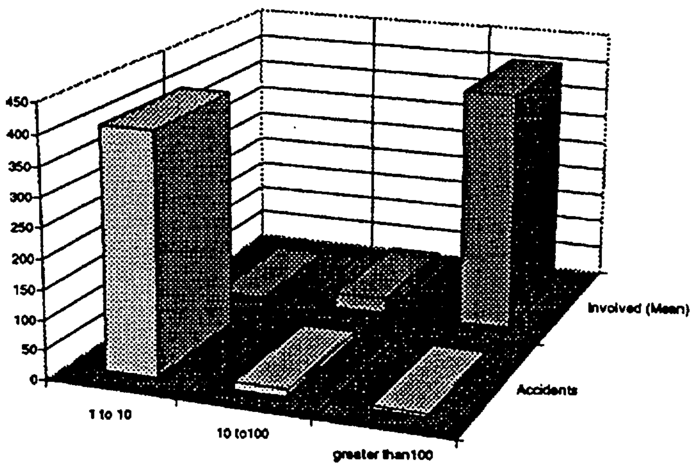

Figure 2: Comparison of Radiation Accidents Concerning Their Size

TABLE II. ACUTE RADIATION SYNDROME (ARS) PATIENTS WITH VERY SEVERE MYELODEPRESSION WITH AND WITHOUT TRANSPLANTATION OF BONE MARROW (BM) OR FETAL LIVER CELLS (FLC) (BARANOV 1993, 1994)

	Code of Case	Irradiation		Transplantation		Death	
		Type	Dose	Day	Type	Day	Cause
1	3091 Mich	γ, n				5	GIS, RB
2	3090 Bor	γ, n				8	GIS, RB
3	3031 Vas	γ, n	20	—		6	GVS, GIS, RB
4	3056 Kor	γ, β				7	RB, GIS
5	3092 Sek	γ, n		—		12	GIS
6	LASL-II N3	γ, n	20	—		9	GIS, RB
7	Wood River Jct 10	γ	10			21	cardiac arrest
8	1023 Pra	γ, β	14	11	FLC	15	RB, GIS
9	1020 OH	γ, β	12	13	FLC	17	RB, GIS
10	3055 Kosh	γ, β				7	RB, GIS
11	3088 Shu	γ	14			113	Infection
12	1015 Tish	γ, β		13	FLC	14	GIS, ARDS, RB
13	Kjeller	γ	20			13	acute heart failure
14	1017 Vats	γ, β	9	16	BM, h, tcd	18	RB, GIS, ARDS
15	1026 Tit	γ, β	13			20	RB, GIS
16	1009 Sha	γ, β	10	12	BM, id	23	RB, GIS, ARDS
17	3032 Ero	γ, n				14	RB, GIS
18	1010 Kib	γ, β	11	9	FLC	14	RB, GIS
19	Sor Van	γ	>10	4	BM, h, tcd	36	aGvHD, viral infection
20	1012 Bar	γ, β	9			24	GIS, ARDS
21	3061 Ord	γ, β				8	RB, GIS
22	Brescia	γ	12			12	CNS lesion
23	3064 Sav	γ, β				9	RB, GIS
24	1003 Ign	γ, β		6	BM, id	17	RB, GIS
25	3063 Har	γ, β				11	RB, GIS
26	1016 Nov	γ, β	10	12	BM, h, tcd	91	aGvHD, CMV infection
27	1014 Bra	γ, β	11	9	FLC	18	RB
28	3057 Pen	γ, β				13	RB, GIS
29	1004 Top	γ, β	11	7	BM, h1	18	RB
30	1002 Aki	γ, β	9	4	BM, id	15	ARDS, RB
31	1008 Iva	γ, β	8	13	FLC	30	RB
32	1027 Per	γ, β	8	13	BM, id/h ?	24	RB, GIS, GvHD?, ARDS
33	1029 Tor	γ, β	9	14	BM, h, tcd		
34	1031 Kon	γ, β	7			32	RB, GIS, ARDS
35	3046 Sap	γ, n					RB
36	1022 Kom	γ, β	7				
37	3017 Alek	γ, n					
38	3047 Milo	γ, n				52	RB
39	Goiânia D	γ	7				
40	1062 Pros	γ, β	6			21	RB
41	3075 Egor	γ	7	26	BM, id	33	systemic fungal infection
42	1028 Pop	γ, β	6	11	BM, id	48	aGvHD, fungal infection
43	1025 Kur	γ, β				16	RB & TB
44	1001 Sav	γ, β	7	6	BM, h1	25	RB
45	Byc Tu 6	γ	6			17	septicaemia, gut lesion
46	1006 Vers	γ, β	5	9	BM, id	86	aGvHD, infection
47	1005 Sit	γ, β	4	7	BM, h1	34	HvGD, ARF,
48	3065 Ber	γ, n					
49	1034 Pere	γ, β	6			48	RB
50	1007 Kud	γ, β	5				allergic shock
51	3009 Sad	γ, n					
52	1071 Kitc	γ, β	5				
53	1011 Pal	γ, β	5	13	BM, h, tcd		
54	Vinca V	γ, n			BM, unmatched	30	pulmonal haemorrhage
55	Pittsburgh C	x-ray	6	9	BM, Sin		
56	Shanghai 80	γ	5	5	FLC		

BM - Bone Marrow; FLC - Fetal Liver Cells; id - HLA identical; h - HLA haploidentical; h1 - HLA haploidentical with one antigen plus on 2nd chromosome 6; tcd - T-cell depletion; causes of death: aGvHD - acute graft versus host disease; ARDS - adult respiratory distress syndrome; ARF - acute renal failure.; CVS - cardiovascular syndrome; GIS - gastrointestinal syndrome; HvG - Host versus Graft; MV - Cytomegalovirus; RB - radiation skin burns; TB - thermal skin burns.

As it becomes evident from Fig. 2 roughly 90% of the radiation accidents however, involve about one individual only, leaving a tiny fraction of less than a percent actually to be considered as a disaster, amongst which Chernobyl and Goiânia are the most prominent examples.

LESSONS LEARNED ON THE TREATMENT OF THE ARS

From lessons learned 25 years ago it has been believed that about 6 Gy TBI will be a lethal dose to man since the stem cells will all be killed and, consequently, BMT will be required. However, the gloomy perspective of those radiation accident victims submitted to BMT, proved that accompanying injuries and disease turned out to be even more effective in terms of lethality than the bone marrow syndrome itself.

The most pressing questions are on the eligibility for BMT, whether an accident will benefit from BMT and by which degree lethality will increase when submitting a patient to a BMT regimen. As depicted in Table II most of the patients with very severe ARS have died despite BMT. The main reasons seem to be that victims of nuclear accidents almost always suffer from accompanying skin burns and trauma of other organs that reduce the probability of survival further. Adding to that is the arduous donor selection. On the one hand, there is difficulty in obtaining sufficient numbers of lymphocytes able to divide in cell culture for HLA typing. More so, mostly only HLA haploidentical donors can be identified, thus, the graft is prone to rejection by mismatch. The higher frequency of infectious complications for reasons of incomplete gnotobiosis and possibly due to transfusions is remarkable if compared to BMT for other reasons. The above stresses the importance of a conditioning regimen prior to BMT even after accidental total body irradiation. Nonetheless, it seems risky though and questionable to submit critically ill people to such aggressive treatment.

In his publication for the 2nd Consensus Building Conference held in Bethesda, MD last year Prof. Baranov stated (Baranov 1993):

1. BMT will never be needed, provided the individual had been exposed to gamma-neutron or gamma-beta accidental overexposure (predominantly due to inhomogeneity and accompanying burns).

BMT however may prove effective in cases of exposure to high dose gamma sources in irradiation facilities, especially when dose estimates are in excess of 10 Gy TBI.

Are there any other alternatives? The usage of haemopoietic growth factors did not show any harmful side effects [Goiânia 1987]. It may turn out however, not to be too effective either, since the example of the Nesvidge, Belarus, patient demonstrated that even though the granulocytes did recover to about 1 Giga/l the platelets did not.

6. CONCLUSION

Especially the perspective laid out in the last paragraph raises the question of what could be done in case of a severe ARS into a rather gloomy perspective. However, it should have become evident that three lessons can be learned from a thorough analysis of radiation accidents:

1. whenever possible accidents should be analysed in terms of optimising the technical equipment to prevent accidents from happening,

2. proper management plans have to be devised in order to be prepared for radiation medical emergencies, and
3. to intensify the research in establishing a proper prognosis of the ARS as early on as possible in order to decide which patients will benefit most from supportive treatment, haemopoietic growth factors, and BMT. The latter should, however, clearly be considered as a weapon of last resort.

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