

Acute Health Effects and Radiation Syndromes Resulting from the Chernobyl Accident

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HEALTH EFFECTS IN THOSE WITH ACUTE RADIATION SICKNESS FROM THE CHERNOBYL ACCIDENT

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Abstract—The Chernobyl accident resulted in almost one-third of the reported cases of acute radiation sickness (ARS) reported worldwide. Cases occurred among the plant employees and first responders but not among the evacuated populations or general population. The diagnosis of ARS was initially considered for 237 persons based on symptoms of nausea, vomiting, and diarrhea. Ultimately, the diagnosis of ARS was confirmed in 134 persons. There were 28 short term deaths of which 95% occurred at whole body doses in excess of 6.5 Gy. Underlying bone marrow failure was the main contributor to all deaths during the first 2 mo. Allogenic bone marrow transplantation was performed on 13 patients and an additional six received human fetal liver cells. All of these patients died except one individual who later was discovered to have recovered his own marrow and rejected the transplant. Two or three patients were felt to have died as a result of transplant complications. Skin doses exceeded bone marrow doses by a factor of 10–30, and at least 19 of the deaths were felt to be primarily due to infection from large area beta burns. Internal contamination was of relatively minor importance in treatment. By the end of 2001, an additional 14 ARS survivors died from various causes. Long term treatment has included therapy for beta burn fibrosis and skin atrophy as well as for cataracts. *Health Phys.* 93(5):462–469; 2007

interaction of many physiological and pathological mechanisms. Thus, in the present text we use ARS to mean acute radiation sickness.

The first descriptions of human ARS were made by a number of authors in the 1940's and 1950's (DeCoursy 1948; Cronkite 1949; Leibow et al. 1949; Behrens 1953; Hempelmann et al. 1952; Gus'kova and Baisogolov 1953). The principal description of the underlying pathologic mechanisms that result in death from ARS belongs to Rajevisky (1956). The basis of ARS pathogenesis is a disturbance of the physiological recovery of various cellular groups damaged by radiation (Ilyin et al. 1966; Mettler and Upton 1995; MacVittie et al. 1996; IAEA 1998; Gusev et al. 2001). There is predominant damage of precursor or stem cells of hematopoietic cells, skin, epithelium, intestine, and vascular endothelium.

Depending on the dose levels, major manifestations of ARS include signs of hematopoietic depression with concurrent infection and hemorrhage (hematopoietic

The Chernobyl ARS Cases

- 134 ARS cases finally documented
- ~400 ARS cases recorded worldwide
- Chernobyl represents ~ 30% of total ARS experience





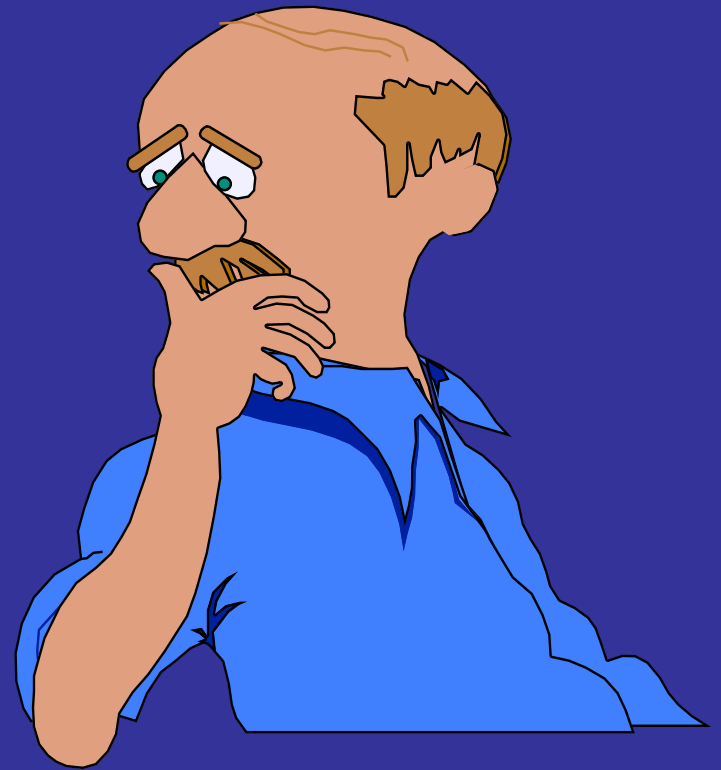
Whole body radiation dose/effect

- 10mGy (1 rad) 1/1000 chance of cancer
 - 100 mGy (10 rads) Chromosomal aberrations
-

- 1 Gy (100 rads) Prodromal symptoms
 - 3.5 Gy (350 rads) LD50 (without treatment)
 - 6.5 Gy (650 rads) LD50 (with treatment)
-

- >12 Gy (>1200 rads) Not survivable

What does ARS
stand for ???



Comparison of acute radiation “syndrome” vs. “sickness”

Acute radiation syndrome	Dose (Gy)	Acute radiation sickness	Dose (Gy)
Subclinical	< 1		
Hematopoietic	> 1 (0.7-4.0)	Mild	1-2
		Moderate	2-4
Gastrointestinal	> 5	Severe	4-6
	(6-8)	Very severe	6-8
		Lethal	>8
CV/CNS	>30 (20-40)		

Radiosensitivity is related to cell turnover rate

- White blood cells/lymphocytes
- Bone marrow stem cells
- Skin/epithelium
- GI tract
- Connective tissue/blood vessels
- Muscle
- Nerve/brain

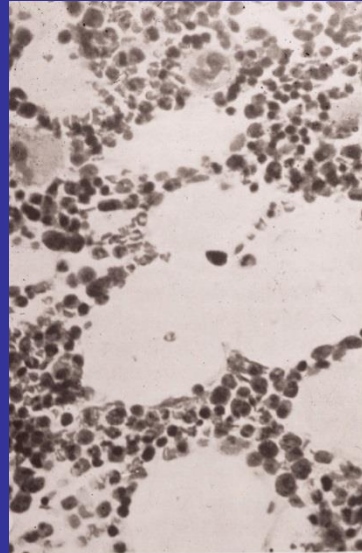
Most
sensitive



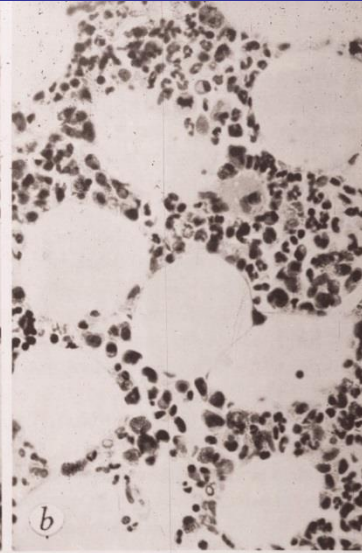
Most resistant

Bone marrow cellularity changes after radiation exposure

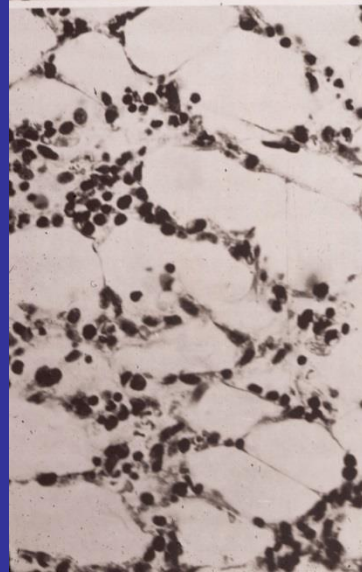
Pre-exposure



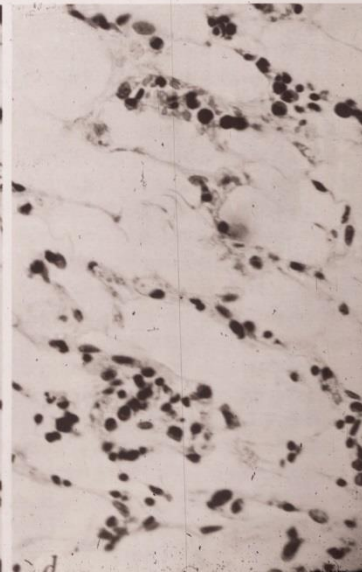
6 days



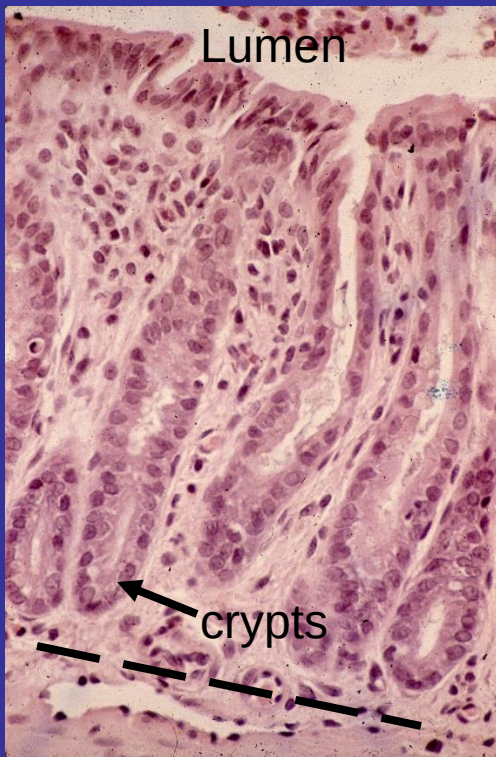
15 days



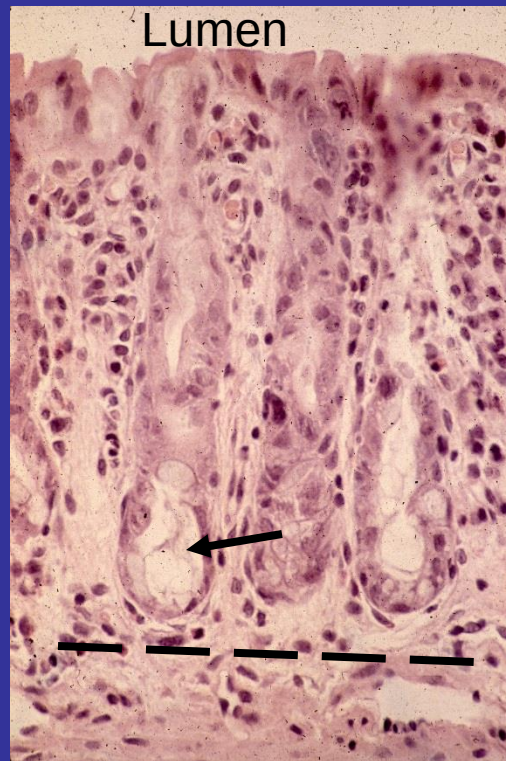
30 days



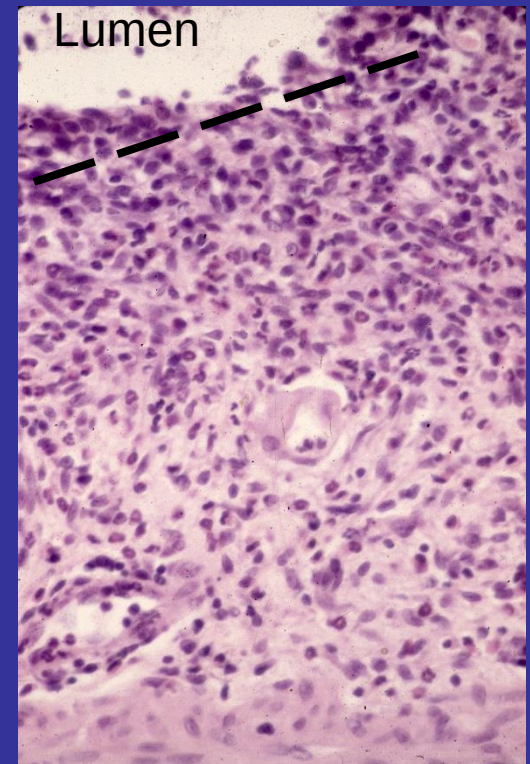
Changes in small intestine after 10 Gy radiation



Pre-exposure

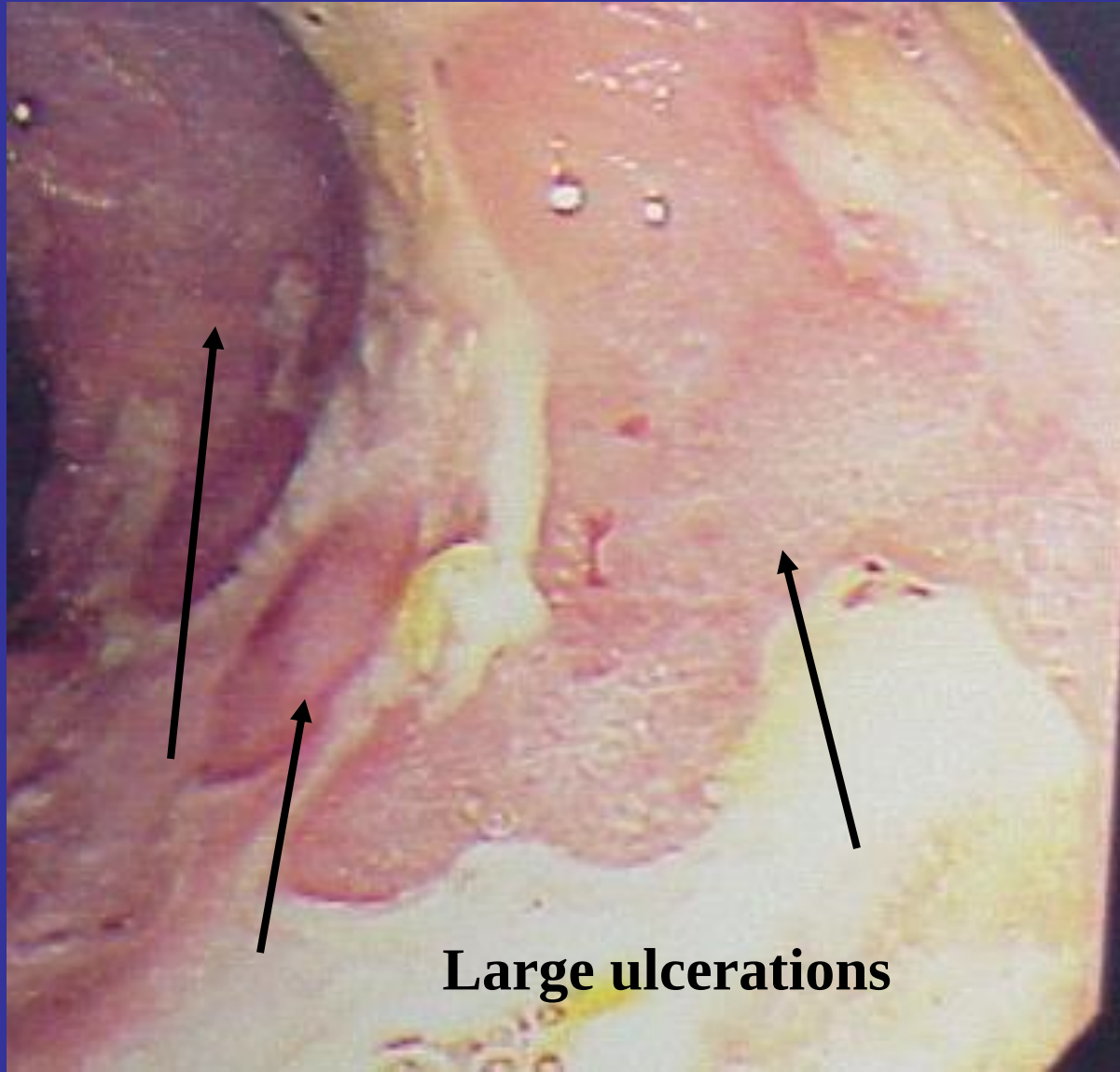


Day 1



Day 7

Radiation ulcers in the bowel



Large ulcerations

How do you know the
dose ???

Initial symptoms
Cytogenetics
Blood picture



Acute radiation “sickness”

Prodromal phase

	Vomiting	Diarrhea	Headache	Body temperature
Mild (1-2 Gy)	> 2 hr 10-50%	None	Slight	Normal
Moderate 2-4 Gy	1-2 hr 70-90%	None	Mild	Increased 1-3h
Severe 4-6 Gy	< 1 hr 100%	Mild	Moderate 4-24h 50%	Fever 1-2 h
Very Severe 6-8 Gy	< 30 min 100%	Heavy	Severe 3-4h 80%	High fever < 1h
Lethal > 8 Gy	< 10 min 100%	Heavy	Severe 1-2h 80-90%	High fever < 1 hr

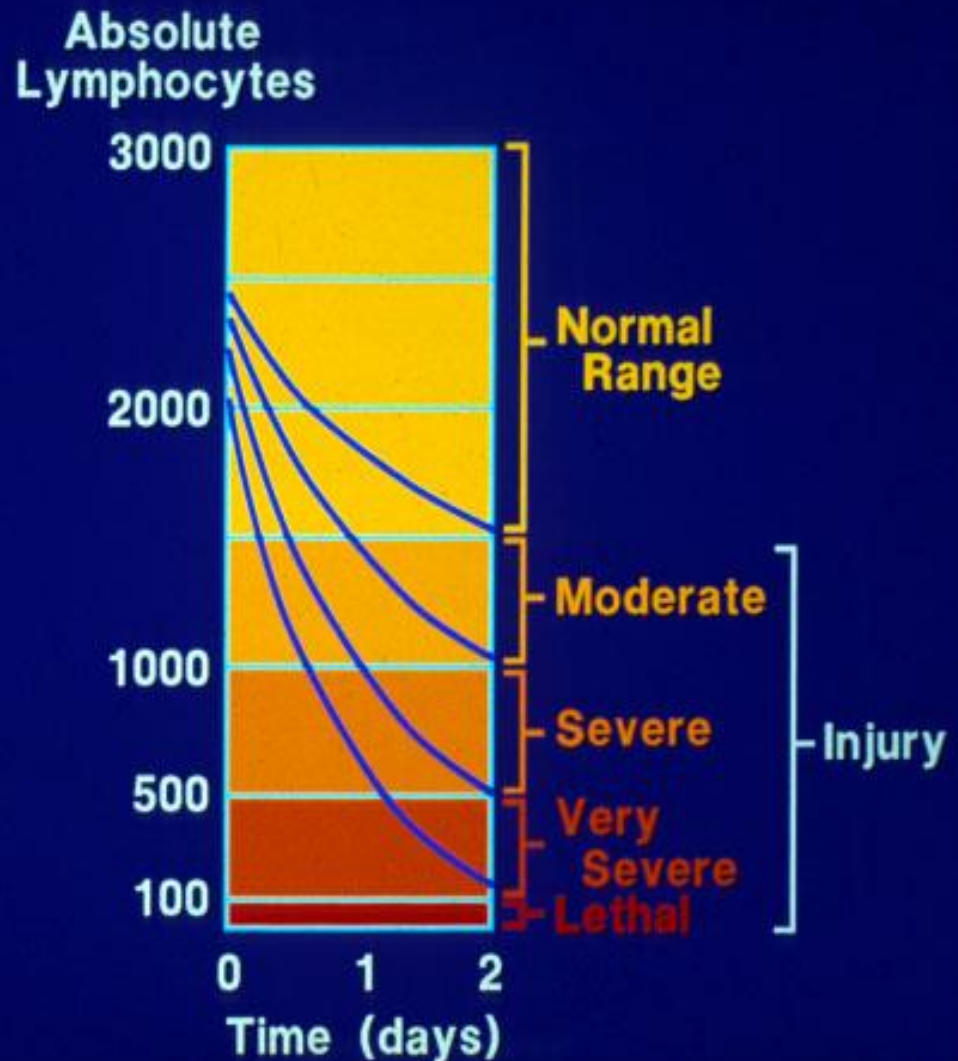
Acute radiation “sickness”

Latent phase

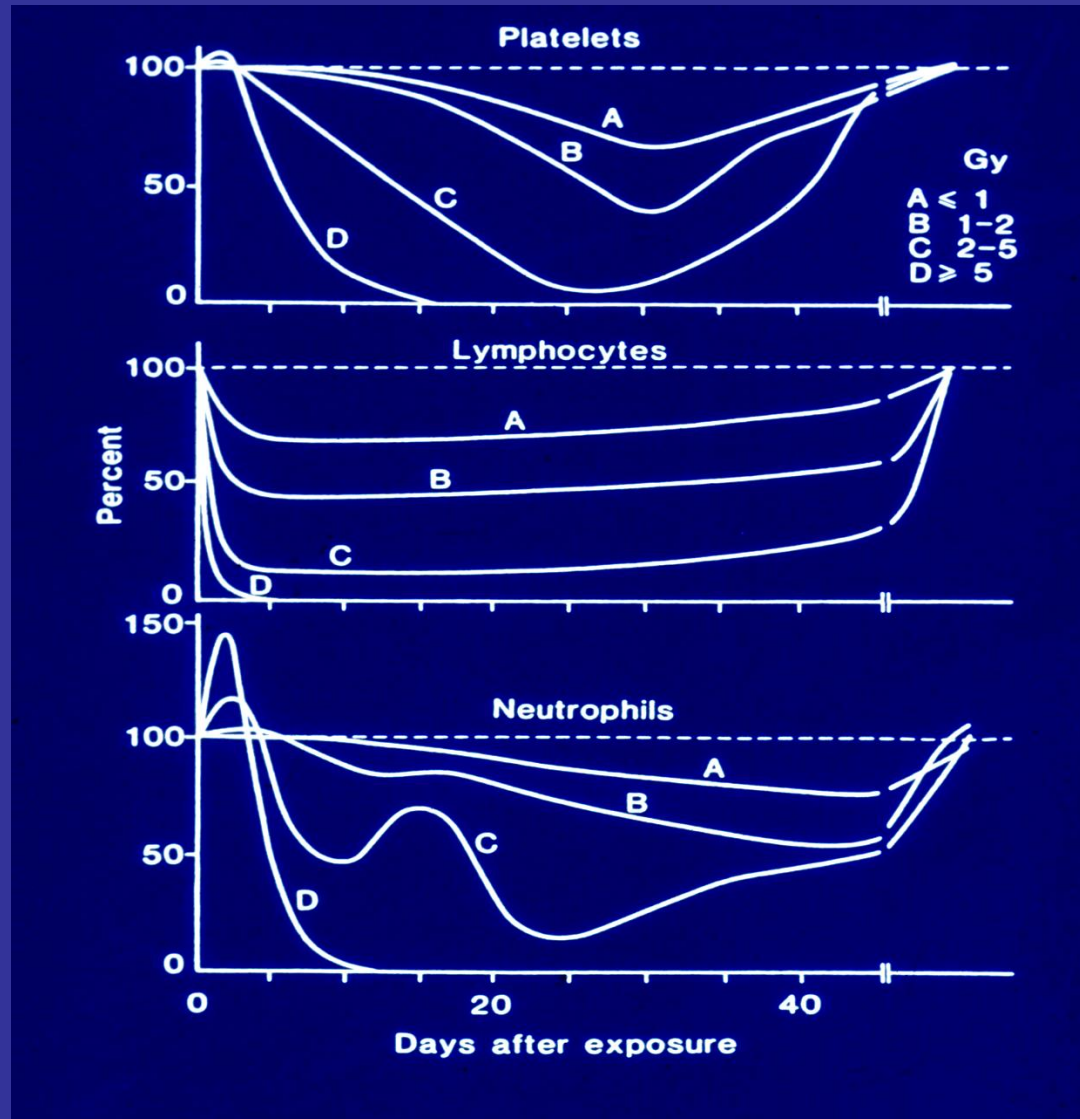
	Lymphocytes G/L 3-6 days	Granulocytes G/L	Diarrhea	Hair loss
Mild (1-2 Gy)	0.8-1.5	> 2.0	None	None
Moderate 2-4 Gy	0.5-0.8	1.5 - 2.0	None	Moderate > 15 days
Severe 4-6 Gy	0.3-0.5	1.0 - 1.5	Rare	Moderate > 11 days
Very Severe 6-8 Gy	0.1-0.3	< 0.5	Days 6-9	Complete < 11 days
Lethal > 8 Gy	0.0-0.1	< 0.1	Days 4-5	Complete < day 10

Lymphocytes are the earliest blood indicator of high radiation doses

Relationship
Between
**Early Changes
in Peripheral
Blood
Lymphocyte
Counts**
and
**Degree of
Radiation Injury**

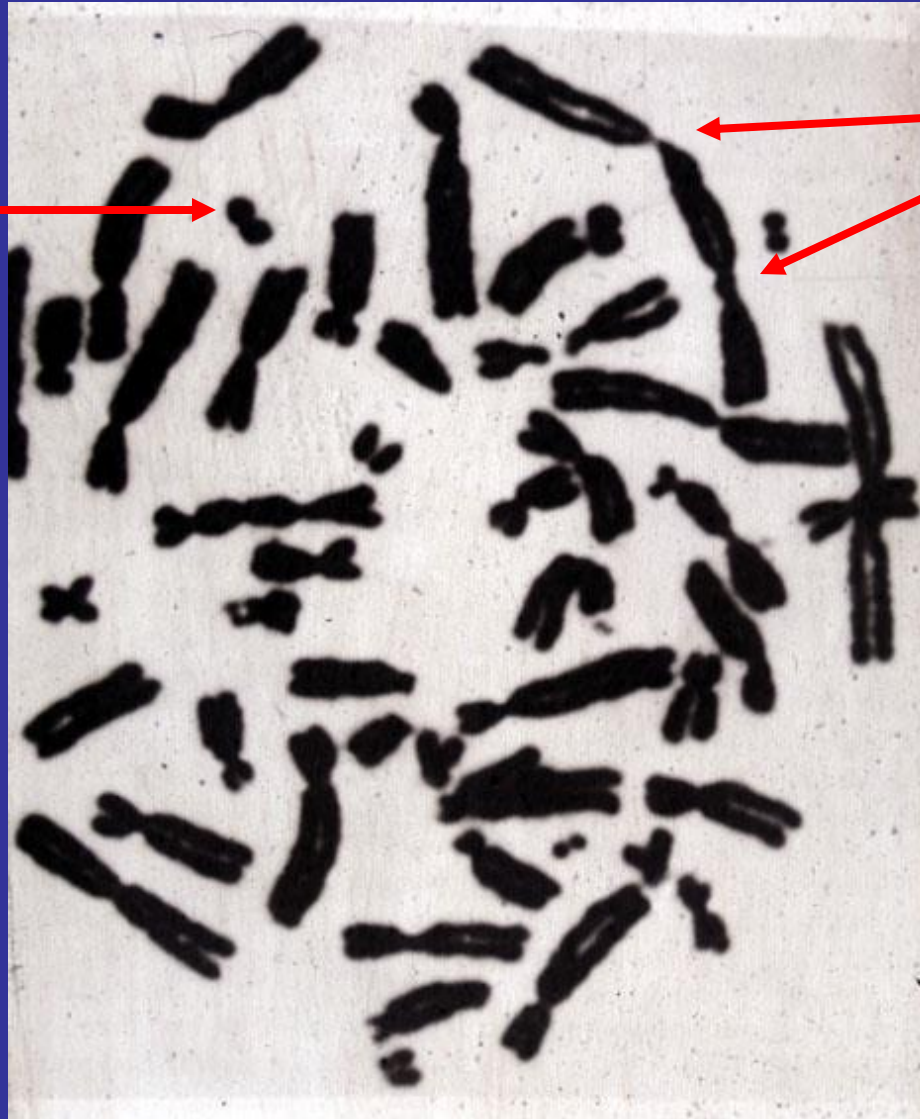


Blood response to different levels of radiation



Chromosome analysis for dose estimate

Fragment
(unstable)



Dicentric
(stable)

Which is the most accurate dose method ?

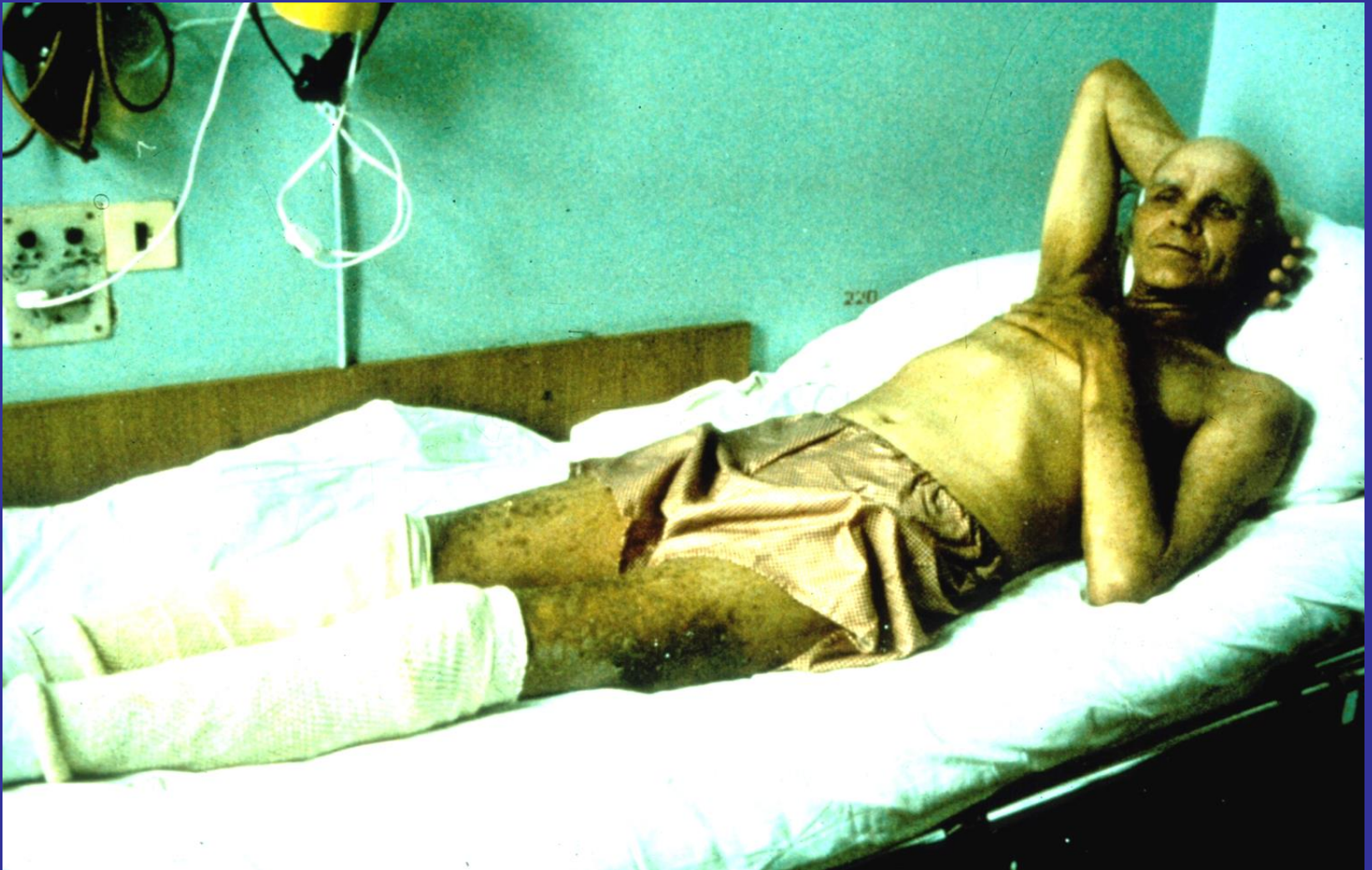
	Patient A	Patient B
Symptoms	4 Gy	6 Gy
Blood response	5 Gy	4 Gy
Cytogenetics	6 Gy	5 Gy

Complicated by beta burns

Complicated by non-uniform gamma radiation

Regardless: we treat the patient not the estimated dose

What was the outcome for ARS patients?



Dose range, number and outcome of 134 patients with varying degrees of ARS

ARS Degree	Dose Range (Gy)	Number of patients	Short term deaths	Number of survivors
Mild (I)	0.8-2.1	41	0 (0%)	41
Moderate (II)	2.2-4.1	50	1 (2%)	49
Severe (III)	4.2-6.4	22	7 (32%)	15
Very severe (IV)	6.5-16	21	20 (95%)	1
Total		134	28	106

Doses, number and outcome of 134 patients with Acute Radiation Sickness

ARS Degree	Dose Range (Gy)	Number of patients	Short term deaths	Number of survivors
Mild (I)	0.8-2.1	41	0%	41
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Severe (III)	4.2-6.4	22	32%	15
Very severe (IV)	6.5-16	21	95%	1
Total		134		

50% lethality about 6.5 Gy



Time and cause of short term ARS fatalities

Time (days)	Number	Cause
14-23	15	Skin or intestinal injury
	2	Pneumonitis
24-48	6	Skin or lung injury
	2	Marrow transplant complications
86-96	2	Skin and kidney injury
112	1	Brain hemorrhage

General treatments

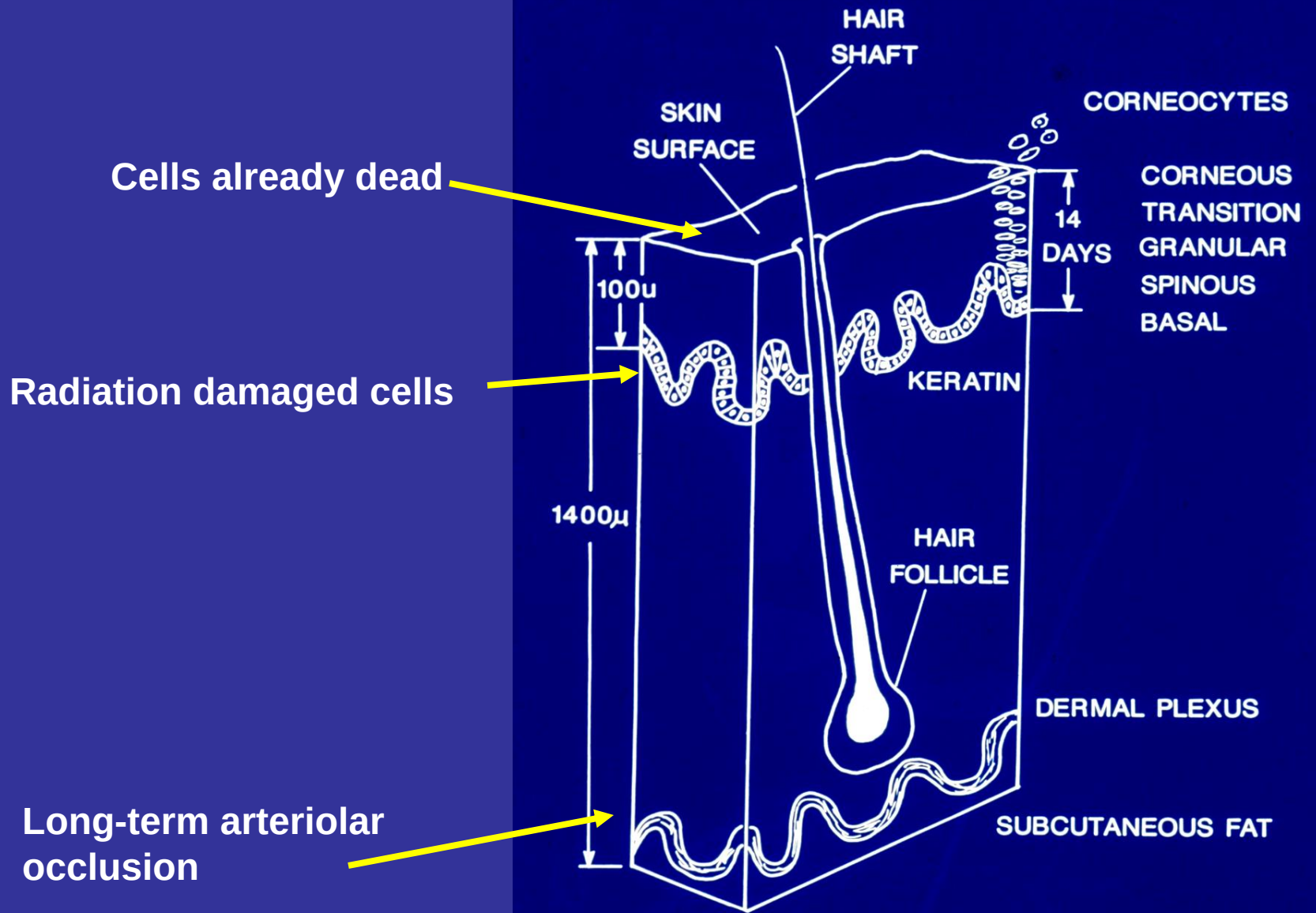
- Prophylactic and therapeutic antibiotics
- Gamma globulin
- Antiviral agents
- Parenteral nutrition and electrolytes
- Transfusions (platelets and red cells)
- Topical skin therapy
- Detoxification (plasmapheresis and absorption)
- Reverse isolation
- Anticoagulation
- Allogenic transplants (13), fetal liver cells (6)

Were bone marrow transplants useful in the Chernobyl experience ?

- 1 survived 8.7 Gy (recovered native marrow) = **survival about 5%**
- 3 Chernobyl patients died as a result of complications
- 4 Chernobyl patients (6-8 Gy) survived without transplant
- Transplantation at doses below 9 Gy only worsened the ARS therapy results
- 1/34 worldwide (survival < 3%)

Chernobyl ARS bone marrow survivor (8.7 Gy) and physicians





- Skin doses exceeded bone marrow doses by a factor of 10-30
- Some patients had skin doses in the range of 400-500 Gy (40,000-50,000 rads)

Skin Changes with acute radiation exposure

2-6 Gy	Transient erythema 2-24 h
• 3-5 Gy	Dry desquamation 3-6 wks
• 3-4 Gy	Temporary epilation 3 wk
• 10-15 Gy	Erythema 18-20 days
• 15-20 Gy	Moist desquamation
• 25 Gy	Ulceration/ slow healing
• 30-50 Gy	Blistering, necrosis at 3 wk
• 100 Gy	Blistering, necrosis at 1-3 wk

Acute beta burns- Chernobyl



“Cutaneous” syndrome

56/134 patients, acute burning pain or itching, skin edema in few hours



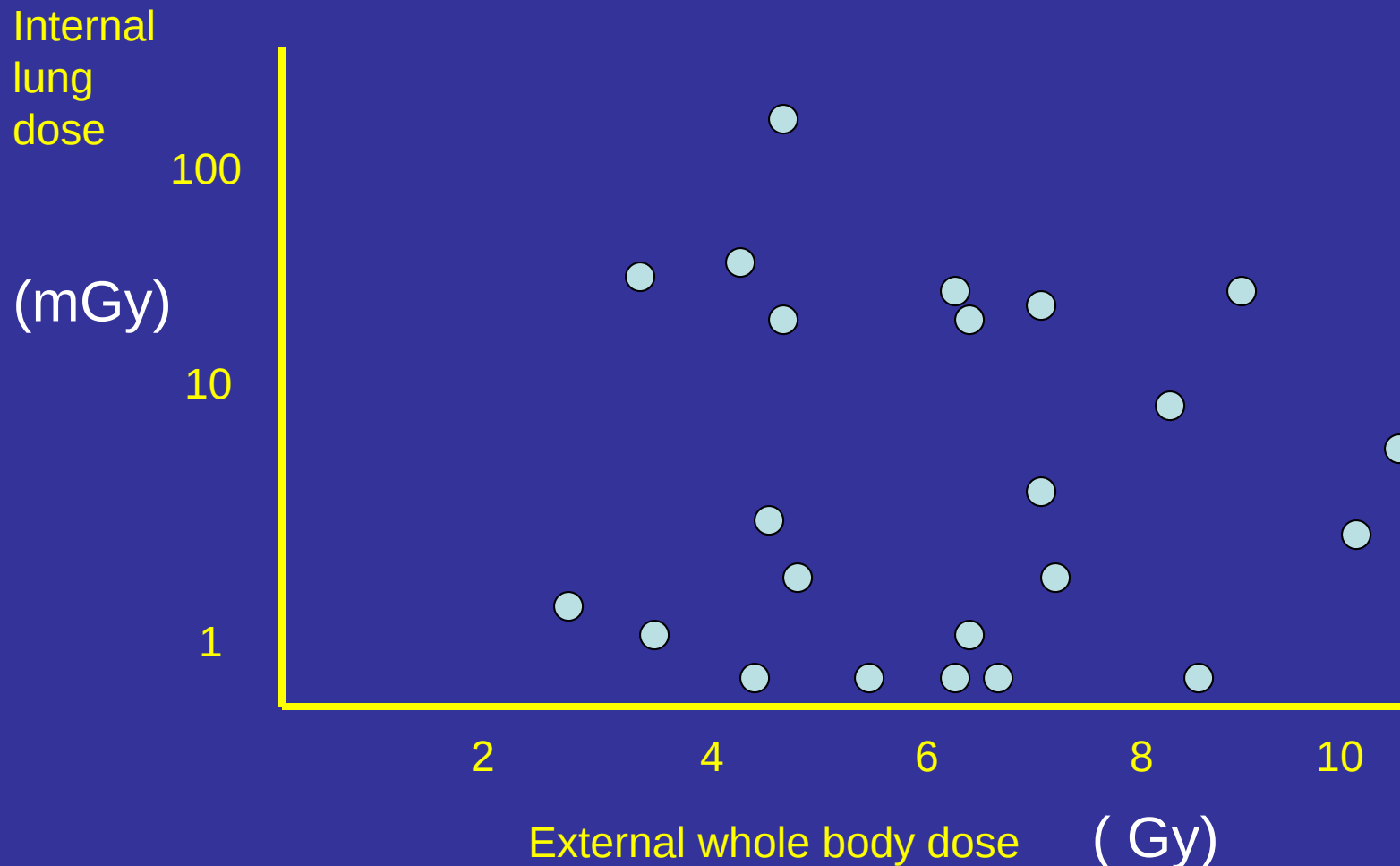
Relationship of ARS grade to percent of total body radiation skin burns

ARS grade	Number of patients	1-10 % burn	10-50% burn	50-100% burn	Skin dose (Gy)
I	31/41	2	1	0	8-12
II	43/50	2	9	1	12-20
III	21/22	3	15	3	20-25
IV	20/21	1	10	9	> 20
Total	115/134	8	35	13	

6.5 Gy LD/50 includes these burns

Relationship of external dose to internal lung dose

(about a factor of 1000 difference or 0.1%)



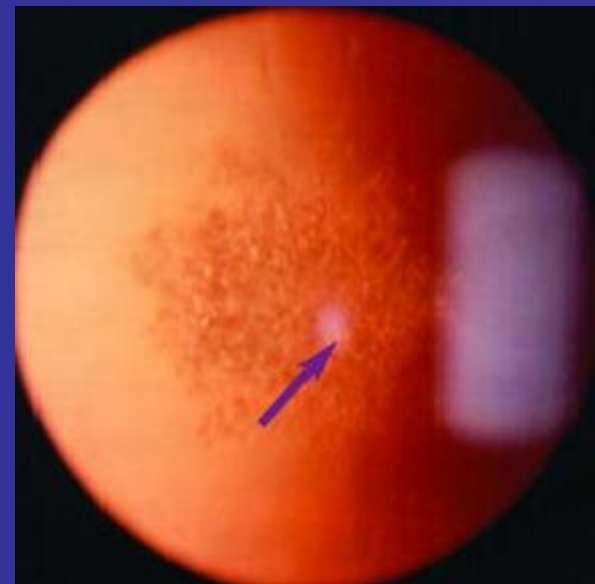
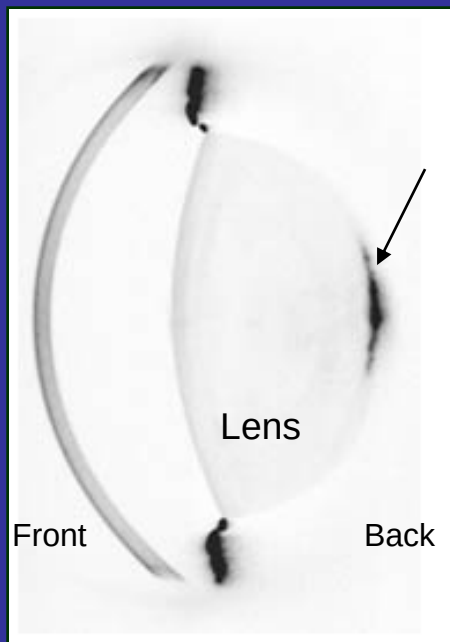
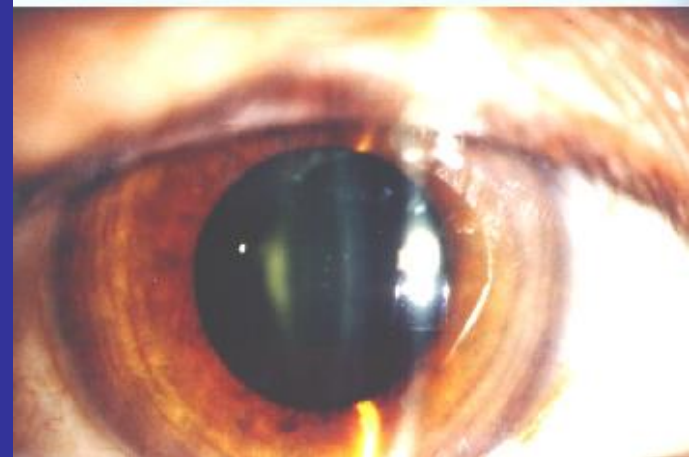
Medical follow-up after high exposures



Chernobyl reactor worker - healed beta burns







Vano
Worgul

Cataracts (as of 2000)

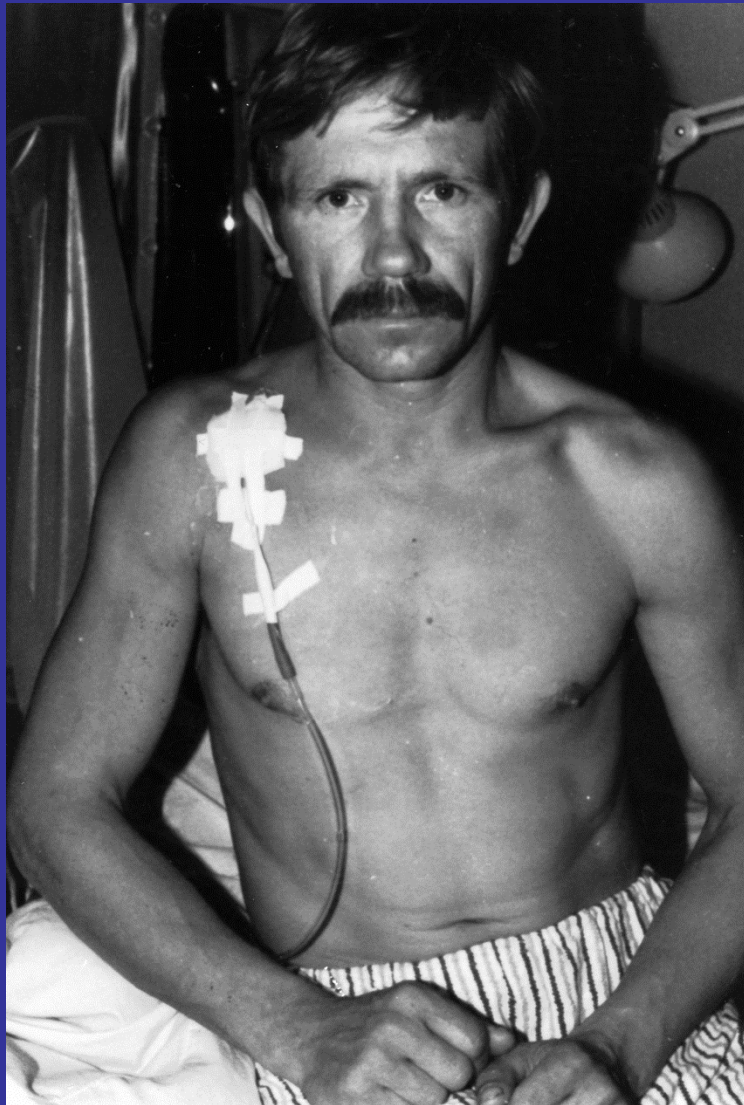
- At least ARS 17 survivors have developed cataracts
- The majority with doses WB external doses > 2 Gy
- Dose to lens complicated by ? beta dose
- Most occurred 3-8 years post exposure
- Surgery was effective and non-complicated

ARS degree	Cataracts by 10 years
Mild	5 %
Moderate	15%
Severe	85%

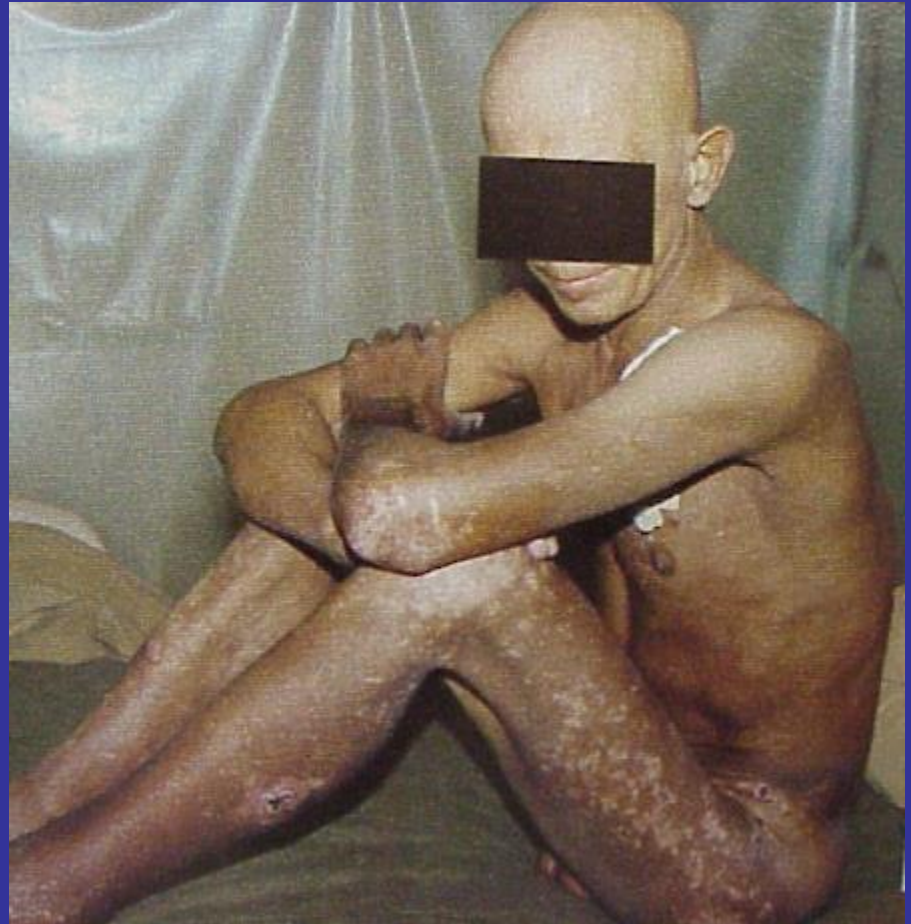
Late lethality of 14 ARS survivors 1987-2001

Year	ARS grade	Cause
1987	II	Lung gangrene
1990	II	Ischemic cardiac disease
1992	III	Ischemic cardiac disease
1993	I	Ischemic cardiac disease
1993	III	Myelodysplastic syndrome
1995	I	Lung tuberculosis
1995	II	Liver cirrhosis
1995	I	Fatty embolism
1995		Coronary heart disease
1996	II	Myelodysplastic syndrome
1998	II	Myelomonoblastic acute leukemia
1998	II	Liver cirrhosis
1998	II	Coronary heart disease
2001	III	Coronary heart disease

Belarus industrial irradiator accident

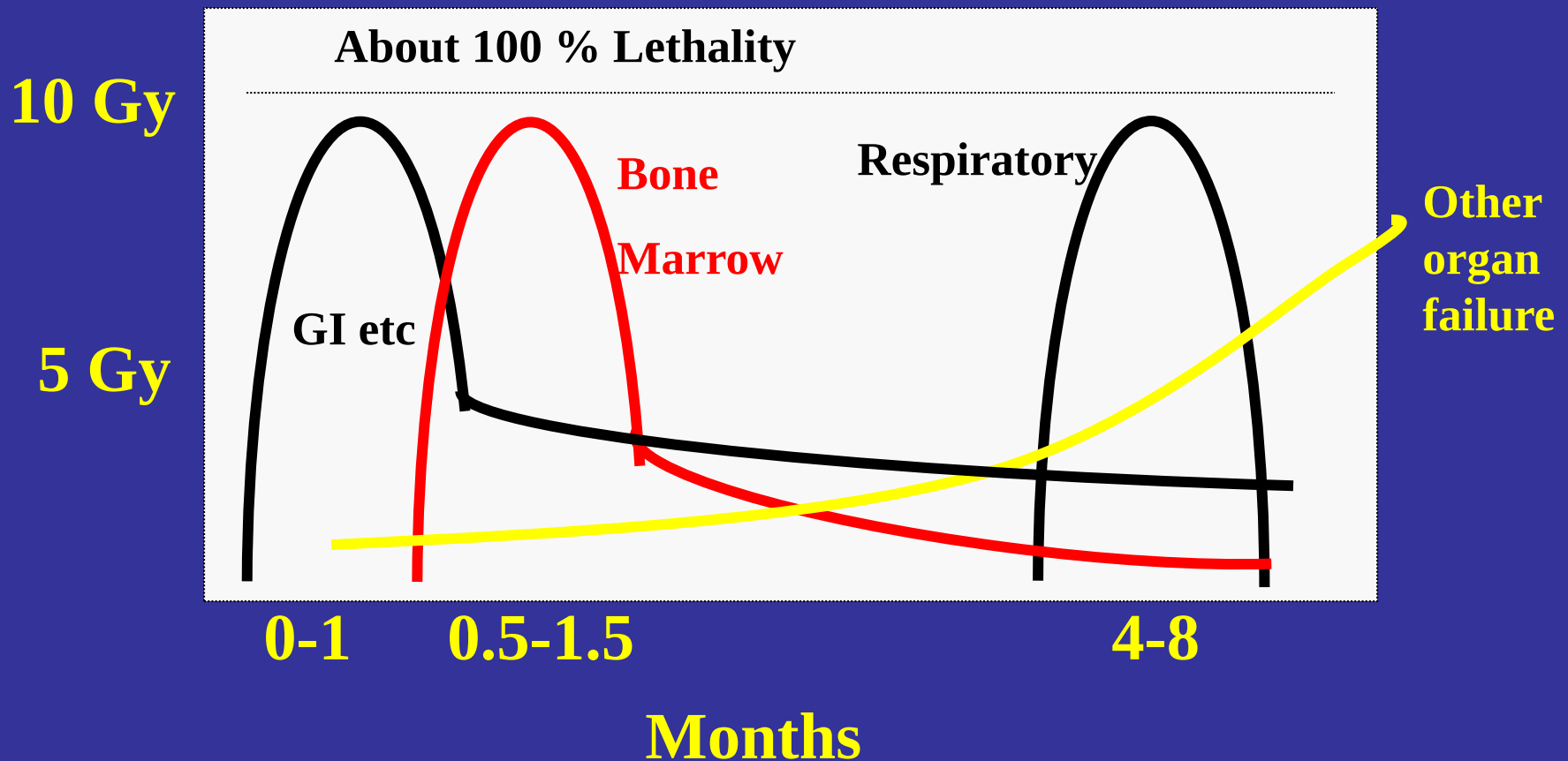


24 hours post exposure



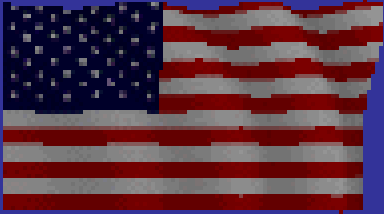
90 days-
pulmonary
failure death

Acute causes of death at various times following whole body exposure



Acute health effects lessons from Chernobyl

- Triage by symptoms and blood count
- Possibly hundreds or more persons needing reverse isolation, bone marrow stimulation, antibiotics, antivirals etc
- Combined injuries adversely affect outcome
- LD/50 with good medical treatment is about 6.5 Gy with skin injuries
- Without skin injuries LD/50 is possibly 6-8 Gy but not higher



Thank you