NUCLEAR SECURITY TECHNOLOGIES

Ref: FOI2024- 065

[redacted]

26 July 2025

Dear [redacted]

Further to our previous correspondence regarding your request for the following information:

** A fresh search of the Merlin database using the search term 'blood', as opposed to 'blood testing', and the total number of documents found using that term, with their dates and titles*
** A copy of the following documents:*

051801.pdf, Health Effects of Former British Atomic Tests at Maralinga, 6/1/1981
900252.pdf and 900253.pdf, Third meeting of panel N5, 16/4/69
AustC_BK06_126.pdf, Blood Results Table, no date
Your request has been handled as a request for information under the Freedom of Information Act 2000 (the Act).

We can confirm that AWE hold all of the information in scope of your request.

Firstly, we have conducted a fresh search of the Merlin database using the search term 'blood'. The total number of documents found are the same amount as previously disclosed. The dates and titles have already been provided to you in FOI2023-026.

In relation to the copies of the three documents requested:

051801.pdf, Health Effects of Former British Atomic Tests at Maralinga, 6/1/1981:

AWE were unable to find any documents with the title '***051801**.pdf, Health Effects of Former British Atomic Tests at Maralinga, 6/1/1981'.* However, we have provided the document titled '***051801**.pdf, Health Effects of Former British Atomic Tests in Australia, 6/1/1981' . We have redacted some of the information under section 40 of the Act as it is deemed personal data. Please see attached.*

900252.pdf and 900253.pdf, Third meeting of panel N5, 16/4/69:

*Please see attached redacted copies of '**900252.**pdf and **900253**.pdf, Third meeting of panel N5, 16/4/69.* The documents have been redacted under section 40 of the Act as it is deemed personal data.

AustC_BK06_126.pdf, Blood Results Table, no date

We are withholding the document titled '***AustC_BK06_126.**pdf, Blood Results Table* ' under section 21 of the FOI Act (Information accessible to applicant by other means). Information in scope of your request can be found at the link below:

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AWE NUCLEAR SECURITY TECHNOLOGIES

AustC_Bk06_126_Prop_redact_Redacted.pdf

Please remember to quote the reference number above in any future communications. If you have any queries regarding the content of this letter, please contact this office in the first instance.

If you are unhappy with the way your request has been handled you have a right to request an internal review within 40 days of receiving this letter, by writing to information.requests@awe.co.uk or our postal address: Information Requests Team, AWE Aldermaston, Reading, RG7 4PR. If you are still unhappy after an internal review has been completed, under the provisions of Section 50 of the Freedom of Information Act 2000 you have the right to take your complaint to the Information Commissioner's Office. Please note the Commissioner will generally not consider a complaint until you have exhausted AWE's internal complaints process.

Yours sincerely,

AWE Information Requests Team

64

DEPARTMENT OF DEFENCE

RUSSELL OFFICES
CANBERRA, A.C.T. 2600

IN REPLY QUOTE: PC 334/3/3

16 January 1981

Mr [redacted],
British Defence Research and
Supply Staff,
[redacted]

HEALTH EFFECTS OF FORMER BRITISH ATOMIC TESTING IN AUSTRALIA

The Department of Defence has been for some time engaged in compiling information for use by the Department of National Development and Energy in connection with the health effects of former atomic testing in Australia. As you know, National Development has been directed by the Government to, in the first instance, process enquiries from persons who are concerned about the possibility of injury having been suffered as a result of involvement in the tests.

2. The attached copy of an extract from "Lincoln at War" refers to Richard E. W. Nettley, a RAF Navigator on exchange posting, who was part of the crew of one of the Lincoln aircraft which were involved in the atomic tests at Emu, South Australia in 1953.

3. Air Force Office has confirmed that Flight Lieutenant R. E. W. Nettley [redacted], an exchange RAF Navigator, was part of the crew of Lincoln [redacted]. In 1954 he developed onychia which in the opinion of a dermatologist was possibly caused by exposure to radiation. I understand that his medical documents would have been returned to the United Kingdom on completion of his exchange posting.

.../2

051801

4. Although no query has been received in respect of Flight Lieutenant Nettley, you may care to enquire after his current health. If his service and medical records can be located it would also be useful for our purpose to have:

- any record of exposure to radiation during the tests; and
- details of any illness reported or treated after the tests.

5. I am copying this letter to the Department of National Development and Energy.

[redacted]
Acting Assistant Secretary
Policy Secretariat

EXTRACT FROM
LINCOLN AT WAR GARBETT & GOULDING
PUBLISHED BY IAN ALLEN 1979.

fly, of course, though reputed to be slightly lighter on the controls. (Perhaps Australian pilots were stronger!) It is interesting to record the comments of an experienced RAAF Lincoln pilot, Syd Gooding, DFC, who did a tour on Lancs during the war:

'My impressions of the Lincoln are that it was a comfortable aircraft and easy to fly. It was very light on the controls, particularly in minor adjustments of attitude where one only needed forefinger and thumb. However, if one wished to make rapid attitude changes in bank it was a different question; one hand on top and one hand on the bottom of the wheel and wind it around with all the strength one could muster. I found that it helped to reduce power on both motors on the inside of the roll.

'Having always enjoyed aerobatics I used to tip the Lincoln around quite a bit. A favourite manoeuvre was a "peel-off" from a vertical bank which impressed the crew somewhat but not the second pilot, he'd get airsick. At times I rolled past the vertical but the Lincoln pulled through beautifully and always felt as if she would "Barrel Roll" without difficulty. I was more fearful of the consequences of being found out than of the manoeuvre itself and hence never attempted it. When flying at a pageant held at Williamstown, our big fighter base, I mixed it with the fighter boys and did buzz circuits for landing. I'd roll on about 45° of bank and pull round, and found that the old Lincoln coped quite well. To me it was a very satisfying circuit – far more so than the long down-wind, cross-wind and finals of the conventional approach.

'I only witnessed one "beat-up" with a Lincoln; it was at Amberley. A senior pilot put on the show and it demonstrated that the Lincoln was no slouch. This pilot hammered around under 500ft, steep-turning port and starboard at 50-60 degrees bank and hardly got beyond the boundaries of the airfield.'

At the other end of the scale, in complete contrast, Alan Underwood, recently retired air correspondent of the *Courier Mail* (Brisbane) gives his lasting impressions:

'I flew in Lincolns as a RAAF Reserve officer (gunner and wireless operator) during the period they were at Amberley and Townsville. I took part in several exercises with them up at Manus Island (the extreme north of New Guinea), both in the standard Australian-built bombers, and the long-nosed version.

'All I can say is RAAF Lincolns were like all British-designed aircraft, an experiment in what the human airman could possibly endure physically. And with as many little hooks and jagged bits added afterward to make his existence in the beast even more trying. I think our Amberley Lincolns' decibel (db) rating in the cockpit and at the navigator's and w/op tables was about 100, which as you probably know is pain threshold. I may be the only person to have flown in a Lincoln with an umbrella up. This was as a newspaper correspondent in one of the Amberley bomber versions, flying from Amberley to New Guinea, riding in the bomb aimer's nose compartment: there wasn't enough Bostik glueing in the perspex panelling and the rain poured in.'

Both 'home' bomber squadrons were involved in the UK atomic trials carried out in central Australia: No 6 operating from Woomera itself, and No 2 from RAAF Richmond near Sydney, in company with an American contingent. Naturally enough the Australian population was very anxious that the atomic cloud did not drift over the populous SE region of the country, and the explosion was delayed for three weeks before the right conditions prevailed. During this waiting period, the No 2 Squadron contingent lived rather primitively under canvas, the best accommodation having been surrendered to the Yanks, of course.

The first device was detonated on 15 October 1953 and No 6 Squadron carried out the initial tracking of the nuclear cloud. The Americans took over from No 6 on a continuous tracking basis, and on the following day No 2 Squadron took over from the USAF B-29s. Pilot Officer A. Stapleton with Pilot Officer John H. Cooney as co-pilot took A73-25 up to 10,000ft to establish contact with the cloud, which by then had spread into a thick, brownish coloured layer. Their task was to pinpoint the centre of the cloud. An air filter was installed under the starboard wing, and a geiger counter by the signaller's seat.

Headings were flown back and forth through the cloud until readings reached their peaks, thus the centre and pattern of the cloud were established. Auxiliary fuel tanks were carried in the bomb bay, and the Lincoln remained airborne for just over 12 hours, landing back at Richmond very low on fuel and very dirty. The Americans gave the crew a wide berth. It was early days for this sort of business and in their innocence of the effects of exposure to radiation the crew (which included an RAF navigator on exchange posting, Flg Off Richard E. W. Nettley) took their Lincoln back to Amberley, where it was banished to the farthest corner of the airfield. There it was to spend the rest of its days, its fuselage marked with large purple crosses.

The system in its inimitable fashion decided the crew should be blood-checked, and the appropriate signals went forth, but without explanation as the exercise was so highly classified; consequently there was no

degree of urgency appreciated. By the time the signals caught up with the crew early in 1954, it had dispersed, and John Cooney, for instance had by then been posted to No 1 Squadron in Malaya. As a fresh faced young pilot officer, he found himself following the path to Changi Hospital, well worn by airmen suspected of carrying another 'disease!

With the departure of No 1 Squadron to Malaya in July 1950, Nos 2 and 6 Squadrons remained as the nucleus of No 82 (Bomber) Wing at Amberley. The Lincolns of the two home-based bomber squadrons ranged far and wide over the country on bombing training, long-range navigation exercises, occasionally search and rescue, displays, and regular defence exercises. The squadrons used Lincolns from the Amberley 'pool' and from the date of No 1's transfer to Tengah, No 6 had the task of training and providing replacement crews, virtually along the lines of an OCU. Both squadrons did good work on flood relief work, mercy flights, medevacs, etc. No 6 also had a commitment to the School of Land/Air Warfare, doing a lot of experimental work on stores and supply dropping. On one of these trial drops a Lincoln's bomb bay was loaded with a huge steel pipe filled with concrete to simulate the weight of a jeep. An Army officer had designed a special quick-release harness which worked a bit too well; as the pipe dropped away from the aircraft it left the parachutes behind in the bomb bay, causing a minor earth tremor as it hit the ground.

No 2 Squadron was to give up its Lincolns first, the last of its Lincoln sorties being on 18 December 1953, the squadron then already converting to the A84 Canberra. On the same date, those crews not converted transferred to No 6 Squadron.

No 6 Squadron was not re-equipped with the Canberra until much later, its last Lincoln flight being on 7 July 1955, and on 11 July, all its remaining Lincolns were transferred to the Lincoln Conversion Flight (still at Amberley) which was then given full squadron status. The unit's main task was to still provide crews for No 1 Squadron.

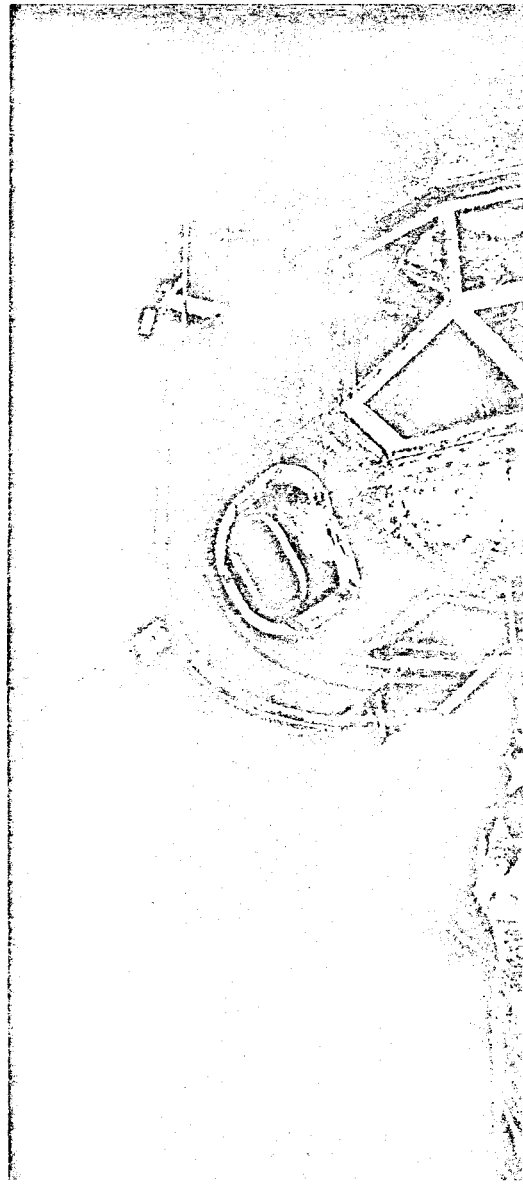
Aussie Specials

Like the RAF, the Royal Australian Air Force had a number of specialist training and experimental units which made extensive use of the Lincoln which was, after all, the only suitably large, 4-engined military aircraft available in the country following withdrawal of the Liberators.

At East Sale, Victoria, a pool of Lincolns was established for use by the various units based there – the Central Flying School and Schools of Air Navigation, Air Armaments (for bombing and gunnery courses) and Photography. Lincolns appeared at East Sale soon after the type had completed service-acceptance trials with 1APU, and for some years the pool consisted mainly of the earlier vintage Lincolns with the rather unreliable Merlin 85 engines, prone to connecting-rod failures, plug troubles, etc, and many of the replacements with later marks of engines were aircraft which had seen considerable service with the squadrons.

One of the best known of the East Sale Lincolns was A73-2, used primarily by the School of Air Navigation. It had been delivered new in August 1946 to No 1 Aircraft Performance Unit at Point Cook, Victoria for service acceptance trials, and for early astro navigation and research work, for which it was specially modified early in 1947.

In its modified form, it closely resembled the Aries series of the RAF, with turrets removed, tail fairing and highly polished natural metal finish, giving it 15/18kts more speed. Progressively, it was fitted with all the modern navigation aids as they came along, keeping it well ahead of the standard Lincolns, many of which were later to be equipped with aids proved in service by A73-2 on its long-range navigation and survey flights.



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THIRD MEETING OF PANEL N-5
(EFFECTS ON PERSONNEL)
SUB GROUP N
THE TECHNICAL CO-OPERATION PROGRAMME
(TTCP)
16th and 17th APRIL 1969

Part 2: Technical Papers and Discussion

Ministry of Defence,
London, S.W.1.

[redacted]

October 1969

CONTENTS - PART 2

AGENDA ITEM 3. A REVIEW OF THE WORK OF THE ATOMIC BOMB CASUALTY COMMISSION

Presented by Dr [redacted]

DISCUSSION

Dr [redacted] asked if there had been any study made in [redacted] in the response to therapy. Dr [redacted] replied that there had been no such study, largely because they did not get there until 33 or 34 days after the events and, in addition, the [redacted] were demoralised. Dr [redacted] inquired if this applied to thermal and blast injuries. Dr [redacted] replied that the situation was too confused to obtain meaningful information.

*This paper will be distributed as soon as available.

[redacted]

[redacted]

AGENDA ITEM 5. EFFECTS OF HIGH ENERGY NEUTRONS

Presented by Dr [redacted]

DISCUSSION

Mr [redacted] referred to Barenson's data on human kidney cell survival in which the RBE varied with the LET and the dose. Dr [redacted] replied that the dose-rate also affected the RBE. Barenson used a 5-6 Mev source.

Dr [redacted] said that he could confirm a number of points on the curves using a 14 Mev source at a lower dose-rate of 10^{11} neutrons/sec.

Dr [redacted] said that the lack of parallelism was due to differing mice strains and to the drugs used. He further stated that the CFU could not be used as an index.

*This paper will be distributed as soon as it is available.

[redacted]

AGENDA ITEM 6. EXPERIMENTAL COMBINED THERMAL AND IRRADIATION INJURIES

Presented by Mr [redacted]

Many articles have been written documenting the enhanced morbidity and mortality that resulted from human combined injuries in the first nuclear weapons explosion, and this report will summarize much of the experimental data that has been obtained from animals given various degrees of combined thermal and x-ray injury since that time. No attempt will be made to estimate the expected incidences of separate and combined injuries that could result in the event of a nuclear explosion from differences in weapon size and type, the population involved, terrain, climatic conditions etc.

Many different laboratory procedures have been used to produce the combined thermal and radiation injuries, and, in this limited review of available material, it has been impossible to absolutely determine the true effects of methodology and timing on the resulting mortality rates. Therefore, the common denominator for most of the studies of this problem is the mortality rate that has been found for varying degrees of both separate and combined experimental injuries.

Brooks et al (4) first studied the effect on mortality in dogs that results from combining a low-temperature contact deep second degree burn given slowly to 20% of the body surface area with 25 or 100 roentgens given at 17r/minute with a 1000 KVP roentgen ray apparatus. Their results are shown in Table I. The addition to the burn injury of 25 r irradiation increased mortality slightly, but the addition of a non-lethal (alone) 100 r dose of x-ray increased mortality rates markedly. Penicillin, if given daily, increased survival to control levels. The blood culture data obtained in these studies led to the belief that the transient bacteremia seen in 75% of the animals with burns alone (due to low-virulence streptococci) was followed in the combined injury group by invasion (via the wounds) by highly virulent streptococci. This latter phenomenon resulted in the high incidence of fatal septicemias that were later controlled in the penicillin treated groups. The polymorphonuclear leukocyte counts were similarly depressed in all of the irradiated animals, and the changes in the red cell counts were similar in all groups.

These same authors later extended their investigation (9) by showing that the incidence of virulent beta hemolytic Streptococci in the wound was markedly increased in animals receiving combined flash and x-ray (100 r) injuries, while the incidence in the blood was less markedly increased (Table II). In this separate series of experiments a different procedure was used for burning, and the mortality rates were less, ie 10% in the 20% burn group and 25% in the burned and irradiated group, despite using the same x-ray dose and rate of administration. One animal in each group died without a beta hemolytic septicemia. The effect of the type of burn administered in addition to its depth and extent upon mortality is definitely present because another series of dogs given the same extent and degree of burn with a flame contact source showed a mortality rate from the burn alone of 81.2% (10). Penicillin did not affect mortality in this latter series, however.

[redacted]

Alpen et al studied combined thermal injuries in rats (1) using an 80°C water burn to produce a deep second degree burn and a 250 KVP unit to give sub-lethal doses of x-irradiation. Both early (less than 48 hours) and late mortality rates were increased with each combination used, but the greatest increment occurred with the late deaths. Rapid preterminal weight loss was present in each group, but this was related more to impending death and not to the specific type of combination of injury. The LA_{50} for thermal injury was decreased with increasing doses of x-irradiation, but the authors were unable to explain why this potentiation of the shock death occurred with the doses of x-irradiation used, 500r or less. Others have shown various changes in the rat's cardiovascular system when larger doses of x-irradiation are given(12), but those doses were not used here. Even chronically administered doses of 25r or less can increase this early mortality, however.

The same group of investigators studied the hematopoetic and blood coagulation systems of rats given similar types of injuries (5,6). More specifically the studies were performed for individual 15 (B_2) and 25 (B_4) per cent body surface area burns, doses of 100r (X_1) and 500r (X_5) radiation, and three combinations of injury (B_4 X_1, B_2X_5 and B_4 X_{495}). The burn alone produced a persistent reticulocytosis, but 100r of irradiation depressed this phenomenon slightly, and the large x-ray dose reduced it markedly for 15 days. With the combined injury the large burn response obscured the lower radiation dose effect, while conversely the lesser burn and larger radiation dose, when combined, caused changes similar to those resulting from the large x-ray dose alone, although the anaemia developed more rapidly with the combined injury. The combination of both major injuries showed no alteration in the rate of red cell loss from the burned or irradiated controls, but the mortality rates were very high in this group.

The larger burns were found to cause increased red cell fragility, and when reticulocytosis was depressed by x-irradiation, the anaemia became very severe, but the experimental method used precluded correlation of the degree of anaemia with mortality.

The coagulation studies were performed on similar groups of injuries given to rats. The initial three day depression shown in thrombocytes following a burn alone persisted with combined injuries, but the later and characteristic post irradiation depression then occurred in these animals. Despite this, however, the defect in clotting times was not as severe with the combined injury as with the single irradiation injury. No evidence or postulates were presented to explain this discrepancy, however.

Baxter et al (3) studied the combined thermal and x-ray injuries in swine. A 220 KVP x-ray unit delivered 10r/minute to the pigs, and a 10 to 15% total body surface area burn was given using a magnesium powder flash source. Their mortality data are shown in Table III, along with the mean survival time for those animals that died. In the control burned group of

pigs all wounds healed spontaneously, and all animals survived. Two animals died after receiving 400r, and they showed a marked bone marrow depression, scattered organ hemorrhages, and infection in the lungs, liver, spleen and abdominal cavity. The animals receiving the combined injuries showed the clinical radiation syndrome; multiple petechiae and gross hemorrhage; fluid accumulations in the pericardium, thorax and abdomen; massive gut hemorrhage; partial intestinal perforation; and evidence of wide-spread infections. If, however, animals were given streptomycin after the combined injury the mortality rate decreased markedly. Hemograms in both treated and untreated (with streptomycin) combined injury groups were similar, however.

Valeriote and Baker (13) used a radiant heat source to give a 16% body surface area deep second to third degree burn in rats and a 250 KVP x-ray unit to administer moderately large irradiation injuries. Their results are shown in Table IV.

The addition of either a second or third degree burn to the x-ray injury caused a significant decrease in survival time within 8 days for all animals receiving less than 750r, but the decreased survival rate was not significant for rats receiving this 750r dose of irradiation. During the later phases of post-injury recovery (up to 30 days) there was no statistically significant decreased survival except in rats receiving the third degree burn and 750r. Aureomycin did not increase survival rates in animals receiving either 750r and no burn or 750r and a deep second degree skin burn. These authors postulated, therefore, that infection did not play a significant role in their mortality rates.

These same authors (2) also studied the changes in mortality rates that occurred when the thermal injury (deep second degree, 16% body surface area) was administered 4 days prior to or after the x-ray dose of 700r. The 8 day or "gastrointestinal" mortality was increased above that seen with irradiation alone, being maximum when the thermal injury was given 72 hours pre-irradiation. Conversely if the thermal injury was administered after the x-ray dose the early mortality rate was decreased but the late mortality increased. These authors believe that the burn x-ray injury synergism reflected in mortality rates is due to the increased inhibition of regenerating tissues by the burn wound effects.

Korlof studied the same effects in guinea pigs using a minimal 1.2 to 1.5 percent body surface area third-degree burn and 250r as the irradiation dose (189 KVP, 8r/minute). The results are very similar to those obtained by other authors (Table V) and controlled infection studies (not shown in the table) showed that streptomycin decreased the mortality rate, with or without irradiation, to one-sixth the rate resulting from the infected injury. These authors did note that, in survivors, the healing rates for the burn wounds were not different in any group of guinea pigs.

Pearse (8) noted the same phenomena re healing in pigs exposed to a test nuclear explosion, especially if epithelialization had begun. Relative to burn wounds, the problem of absorbing radioactive materials through the wound has been investigated by Solok and Howard (11). They found, in rats, that radioactive Na, I, Sr, Ba, La, Br ,and Y could be absorbed through a second degree scald burn eschar at the rate of the 1/nc per cm^2 skin burn per hour. Third degree scald burns were less absorptive while absorption through intact skin was negligible.

Summary

All of these data confirm the clinical data from earlier nuclear catastrophes re enhanced mortality from combined injuries. Consideration has not been given, in this report, to the mortality that would result from thermal-blast, irradiation-blast, or combinations of all three injuries. It is apparent that the time sequence in which the injuries occur and the experimental methods used have, by themselves, affected the obtained mortality rates. It is also apparent that minimal injuries of either type, when added to a larger injury, increase the mortality significantly.

Many areas remain to be investigated. The reason for x-ray potentiation of the early burn shook death, even if given days earlier, to the animal given the usually non-lethal burn is very obscure and should be investigated. The variable results obtained in some series with antibiotics raise legitimate questions concerning the validity of the belief that the combined injury deaths are due to either truly or relatively increased bacterial virulence.

The need for an impermeable skin protectant is also obvious, as is the need for more information concerning the massive weight loss noted in many of these experiments especially in animals just prior to death. Burn and blast injury combinations have been largely neglected in experimental studies although they may well be the most common type of clinical injury that would occur following a nuclear explosion.

The information, as shown above, is relatively scanty concerning combined thermal-irradiation injuries,and, aside from a few easily measured parameters, remains almost totally concerned with mortality rates. These knowledge deficits should be corrected by extensive experimental investigations of multiple biochemical and physiological problems attendant to the combined injury.

[redacted]

[redacted]

[redacted]

TABLE I

EFFECT OF COMBINED INJURY IN DOGS (THERMAL AND X-RAY)

Injury	Number of animals	Mortality	Blood Cultures
20% B	40	12%	75% +
100r	10	0%	-
20% B + 25r	25	20%	Not stated
20% B + 100r	40	73%	78% +
20% B + 100r + Pen	28	14%	0

TABLE II

BACTERIOLOGICAL STUDY - COMBINED FLASHBURN AND X-RAY INJURIES IN DOGS (Reid et al)

Culture Source	Wound	No. Positive Beta Strep	Per cent
Blood	20% B	1/239	0.42
	20% B + 100r	15/221	6.8
	100r	0/140	0
Burn Wounds	20% B	47/185	25.4
	20% B + 100r	85/159	53.4

[redacted]

TABLE III

COMBINED FLASHBURN AND X-RAY INJURY (SWINE)
(Baxter et al)

Wound/Injury (10 per group)	Mortality	Day of Death
10-15% B	0	
400r	20%	22
10-15% B + 400r	90%	13
Above + Streptomycin (24 hrs)	20%	19

TABLE IV

EFFECT OF COMBINED INJURY IN RATS
(THERMAL AND X-RAY) (Valeriote and Baker)

X-ray Dose	Per cent Survival					
	Day 8			Day 30		
	Degree Burn			Degree Burn		
	0	2nd	3rd	0	2nd	3rd
550r	100	80	80	80	50	60
600-650r	96	83	67	76	60	32
700r	96	45	30	62	18	10
750r	44	40	20	20	20	0

No effect with aureomycin.

TABLE V

RESULTS COMBINED INJURY IN GUINEA PIGS
(THERMAL AND X-RAY) (Korlof)

Injury	Per cent Mortality	Per cent Positive Blood Culture
250r	10.5	3
1.2 - 1.5% B	8.8	0
250r + B	37.7	38

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DISCUSSION

Mr [redacted] referred to work carried out by Dr Clark at Toronto University in which he had determined the LD_{50} over rather longer time periods for mice with 16% burns. He found that between 10 and 14 days after infliction of the burns there was radio-resistance, after 20 days there was radio-sensitivity.

Dr [redacted] said he should point out that the bacterial flora found was not that usually associated with normal burns. Further information was required on burn and mechanical trauma. Dr [redacted] replied that there was good Russian literature on this subject, he considered it to be top-flight work which showed the particularly bad combination of radiation injury with a penetrating abdominal wound. Dr [redacted] said that fractures with burns were fairly common, they were however short of information on infection in mass casualty situations. It could not be assumed that infections in these situations would be the same as infections found under hospital conditions.

Dr [redacted] queried whether the introduction of an α-blocking agent would reduce early shock injury. Dr Lajtha replied that it would and this had been published in Nature. Dr [redacted] said that a basis for understanding water metabolism in the gut could be found in earlier publications on this and on the subject of sodium metabolism.

AGENDA ITEM 7. FREE FIELD RANGE-YIELD EFFECTS DATA FOR HIROSHIMA AND NAGASAKI

Presented By Dr [redacted]

DISCUSSION

Lt Col [redacted] observed that the soldier does not go indoors, unless it is in a tin box or in the earth, the optimum appeared to be a tin box in a trench. Thermal effects were also important. Dr [redacted] - "yes".

Dr [redacted] said there was an argument that you did not need personal dosimetry on the grounds that information would be obtained from area survey; he asked Dr White if he had provided a counter argument. Dr [redacted] said that his own opinion was that a dosimeter was necessary.

Dr [redacted] agreed that there was a difference between building damage and casualties, he was reminded of studies of HE damage in which there were a great many examples of complete building destruction but many survivors. There was a similarity between Dr White's curves and the curves of HE damage and survivors. Dr [redacted] said that the Texas City explosion in fact showed the opposite effect, largely due to the effects of the large amounts of window glass in the buildings. Nevertheless the safer places in structures are identifiable. Dr [redacted] queried how applicable were data from World War II blast damage. Dr [redacted] - "very".

Dr [redacted] said that you could influence peoples behaviour either by a short or a long warning, short warnings were the more effective. Mr [redacted] questioned whether people in fact learnt from experience. From his own experience people became fed up with sleeping in shelters after a while. Dr [redacted] observed that V1 casualties had been considerably reduced by the necessarily short warning.

Dr [redacted] referred to the "Little Harbor Report" (Reference TID-24690) which he felt was relevant to the preceding discussion and which he tabled.

*This paper will be distributed as soon as it is available.

[redacted]

AGENDA ITEM 8. THE ACUTE RADIATION SYNDROME: RELATION OF CLINICAL EFFECTS TO PROGNOSIS. ([redacted] University of Cincinnati College of Medicine)

Presented by Dr [redacted]

This report presents a brief account of research carried out at the Radioisotope Laboratory of the University of Cincinnati for the past nine years reflecting our concern with the diagnosis and treatment of the acute radiation syndrome. These studies are almost entirely derived from patients with cancer in whom curative attempts cannot be made. It has been our tenet that whole or partial body radiation is at least as effective as other forms of palliation.

Insofar as possible patients are selected with a normal hemogram and ability to maintain weight. Those with lymphomata are excluded from the study since the possible rapid destruction of tumor tissue would present changes not found in the more nearly normal subject.

Irradiation has been given with a single Cobalt 60 teletherapy unit at distances of 282 cm from the midline and with exposure rates of 3-6 R/min. Whole body exposure is given through two opposing lateral portals. Partial body radiation is given with a dividing point at the xiphoid although other boundaries are to be investigated in the future.

Each patient serves as his own control with 3-5 week pre-treatment exposure period being compared to a 4-12 week post-treatment observation period. There is careful clinical observation, special psychic and psychiatric interviewing, detailed laboratory tests and a number of special biochemical and other studies of interest.

Two aspects of this work will be presented here. The first is concerned with evaluation of clinical and routine laboratory observations and the second is related to estimates of effects of partial body irradiation to the better documented changes observed in total body exposure.

In the course of our clinical evaluation several episodes of sham irradiation are carried out and in most instances these have preceded the actual therapy. The preparations and procedures for sham are the same as for the irradiation. At no time is the patient informed as to symptoms or signs which he might experience nor is he questioned about such manifestations subsequently - he is simply observed. No incidence of sickness occurs in these cases.

One of our specific interests has been the occurrence and frequency of prodromal symptoms in relation to prognosis. An early hypothesis was that subjects who had received previous radiation therapy would be more likely to have prodromal symptoms and that these would be more severe than in patients who had been so treated earlier. This hypothesis was rejected.

[redacted]

[redacted]

No difference in prodromal findings between these two categories of patients was noted nor was there any difference in hematological findings not attributable to the underlying disease.

Insofar as a dose response relationship is concerned, prodromata were not found below 100 rad. There was a gradual increase in the frequency of nausea and vomiting between 100 and 200 rad, the probabilities being shown in Table 1. These responses vary somewhat from those reported by Lushbaugh (1) but our patients were carefully screened from inferential questioning or subjective stimuli.

The other clinical finding of considerable interest was the lack of change in the incidence of prodromal symptoms with partial body irradiation. In this part of our study patients received irradiation to the upper or lower parts of the body, the separation point being at the xiphoid. The dosimetry of these two situations is shown in Fig 1 and 2. Our highest dose to date has been 300 rad. The clinical response to the partial body irradiation was the same as if the patient received total body irradiation. The frequency and severity of nausea and vomiting were related to dose. It was not possible to distinguish these patients clinically from the total body group.

But in regard to their hematological changes, one is struck by the remarkable paucity of changes following 50-300 rad of this partial body exposure. No difference in response has been observed between upper and lower body irradiation. Although there may be small decreases in certain of these values it would be quite difficult to determine that such an individual had received radiation.

Even early lymphocyte depression was less marked than for comparable degrees of whole body radiation. Using the technique of profile scoring (rank analysis of hematological changes) (2) as modified for previous evidence of disease shows that partial body patients fall between those receiving less than 100 rad and those receiving 100 rad. (See Table 2.)

Thus one might expect less response from the PBR patients by an objective hematological measure.

An extensive battery of psychological and psychiatric studies were carried out (see Table 3). These tests have been designed primarily to demonstrate possible evidence of cognitive impairment. As yet there is no evidence of such change though this negative finding may be due to the poor intellectual quality of our patients. A major problem in this sphere is the development of suitable tests to permit adequate evaluation.

As a result of the lack of evidence of hematopoeitic damage in the partially irradiated patient an attempt has been made to determine the effect of these doses and to estimate at what point the partial body dose would be equivalent to total body radiation.

Bond (3) has derived a curve (Fig 3) for estimating the mortality from exposure of bone marrow with either uniform or non-uniform distribution. An LD_{50} of 285 rad is used and is set equal to a relative stem cell survival of 1.0. Kereiakes and Rogers (4) have measured the actual bone marrow dose in rad for the conditions of bilateral cobalt-60 exposure in the phantom. Thus for the conditions of our study the actual doses may be used with Bond's curve to calculate the relative stem cell survival. This curve has been extended somewhat to explore the effect of higher partial body doses (Fig 4). In this way one can estimate that a midline dose to the lower body of 600 rad (900 R midline air exposure) would be equivalent to a whole body dose of 120 rad and would produce minimal significant hematological effect. At these dose levels, however, and at somewhat higher ones it might be possible to produce other localized effects, eg skin or gastro-enteric.

Further consideration should be given to the employment of human subjects who in the course of their disease receive radiation therapy and can contribute to our understanding of acute effects. Many of the findings in lower animals are not confirmed in the human being.

Our studies indicate that human data can be useful in estimating radiation effects and that patients can serve as important sources of data which cannot be obtained in any other way. Such studies need to be expanded.

REFERENCES

1. In Langham, W.H. (Ed.) Radiobiological Factors in Manned Space Flight, Chapter 5, p. 59-133 Part II, Radiation Effects in Man: Early Effects.

2. Metabolic Changes in Humans Following Total Body Irradiation. DASA-1422, Report for November 1, 1961 through April 30, 1963. DASA Contract No. DA-49-146-XZ-029, Defense Atomic Support Agency, Washington, D.C.

Metabolic Changes in Humans Following Total Body Irradiation. DASA-1844, Report for February 1960 through April 30, 1966. DASA Contract No. DA-49-146-XZ-315, Defense Atomic Support Agency, Washington, D.C.

3. Bond, V.P. Personal Communication.

4. Kereiakes, J.G. and Rogers, J.W. Personal Communication

TABLE 1

STIMULUS (PRODROMAL SYMPTOMS[a]) AT WHICH PROPORTION P WOULD BE EXPECTED TO RESPOND (CINCINNATI DATA)

P	Midline dose (rads)
0.10	58
0.20	86
0.30	107
0.40	125
0.50	141
0.60	157
0.70	175
0.80	195
0.90	224
0.99	292

a. Nausea, vomiting, etc.

TABLE 2

Type of rad	No. of Pts.	Dose	Mean Rad Score
TBR	8	< 100 rad	12.6
TBR	8	100 rad	41.2
PBR	8	100-300 rad	21.3

TABLE 3

(a) Reitan Trails Test, Parts A and B.

(b) Catell's 16 PF IPAT, Form A.

(c) Gottschalk-Gleser Values Inventory.

(d) Wechsler Depression Rating Scale.

(e) Clinical Depression Scale of Gottschalk.

(f) Selected portions of the Wechsler-Bellevue Adult Intelligence Scale.

(g) Clinical Hope and Denial Scales.

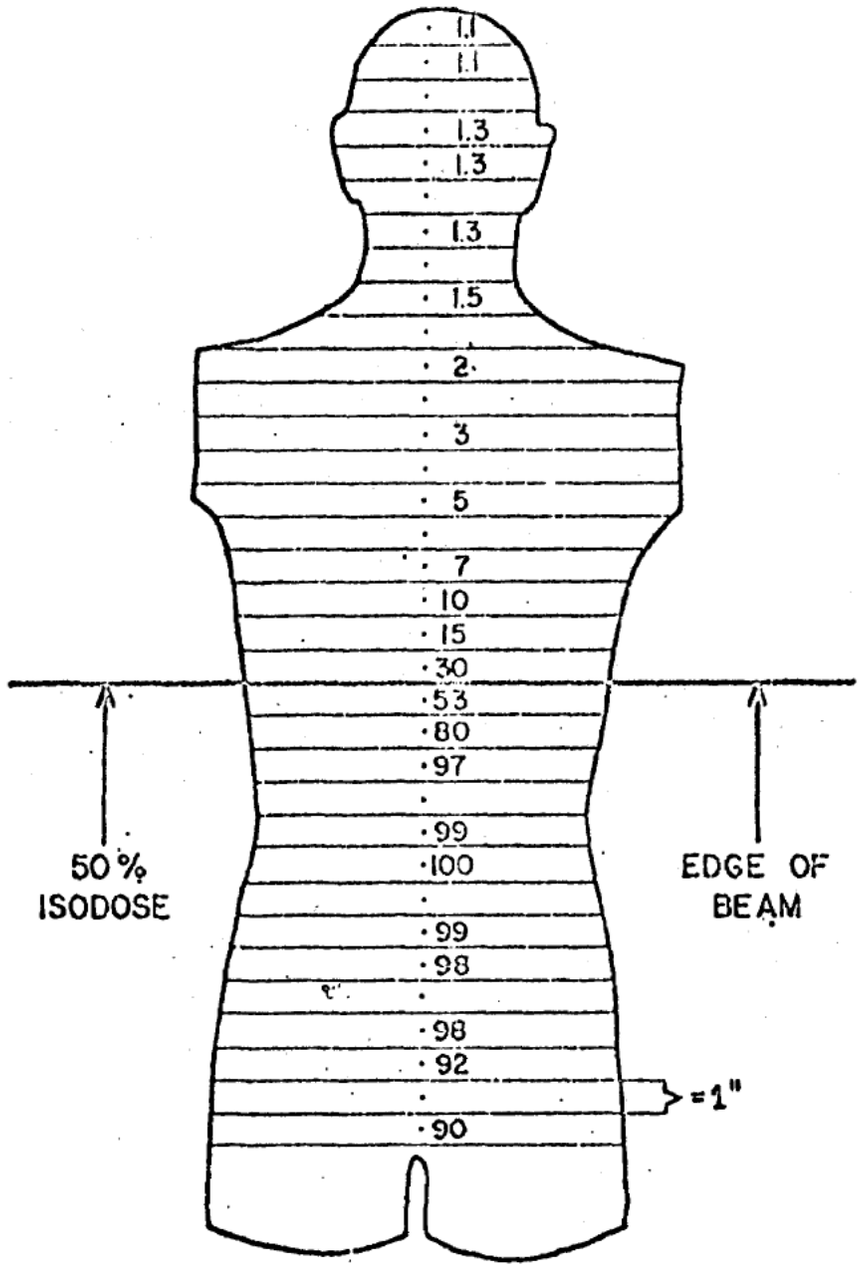
(h) A structured questionnaire designed to pinpoint certain specific dynamics contributing to depression such as separation, guilt, shame and machochism.

(i) A five-minute tape recorded verbal sample.

[redacted]

FIGURE 1

RELATIVE DOSES FOR ^{60}Co PARTIAL BODY (LOWER) IRRADIATION AS IRRADIATION AS MEASURED WITH TL-100 POWDER AT CENTER OF RANDO PHANTOM LATERAL IRRADIATION.

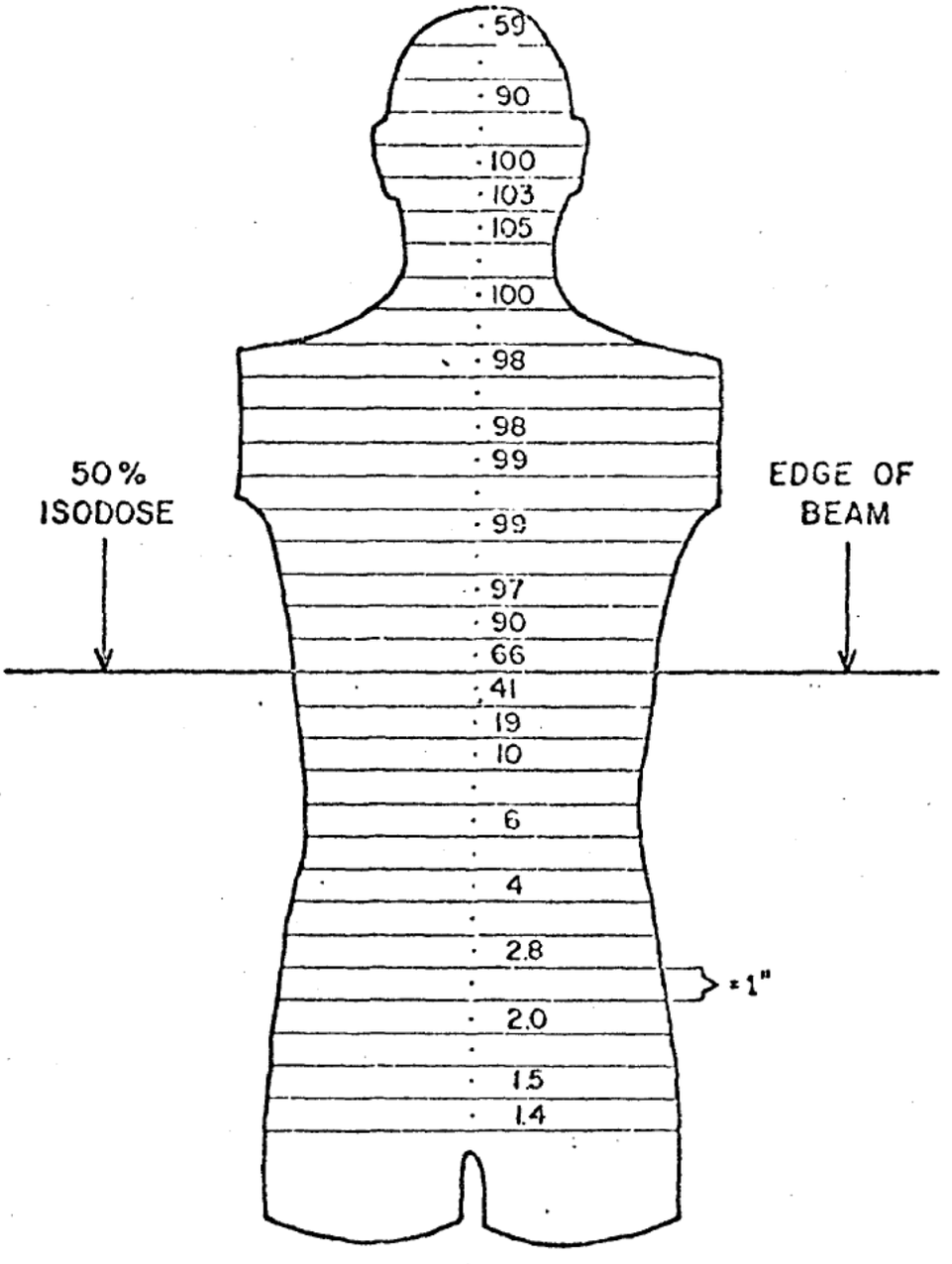


[redacted]

[redacted]

FIGURE 2

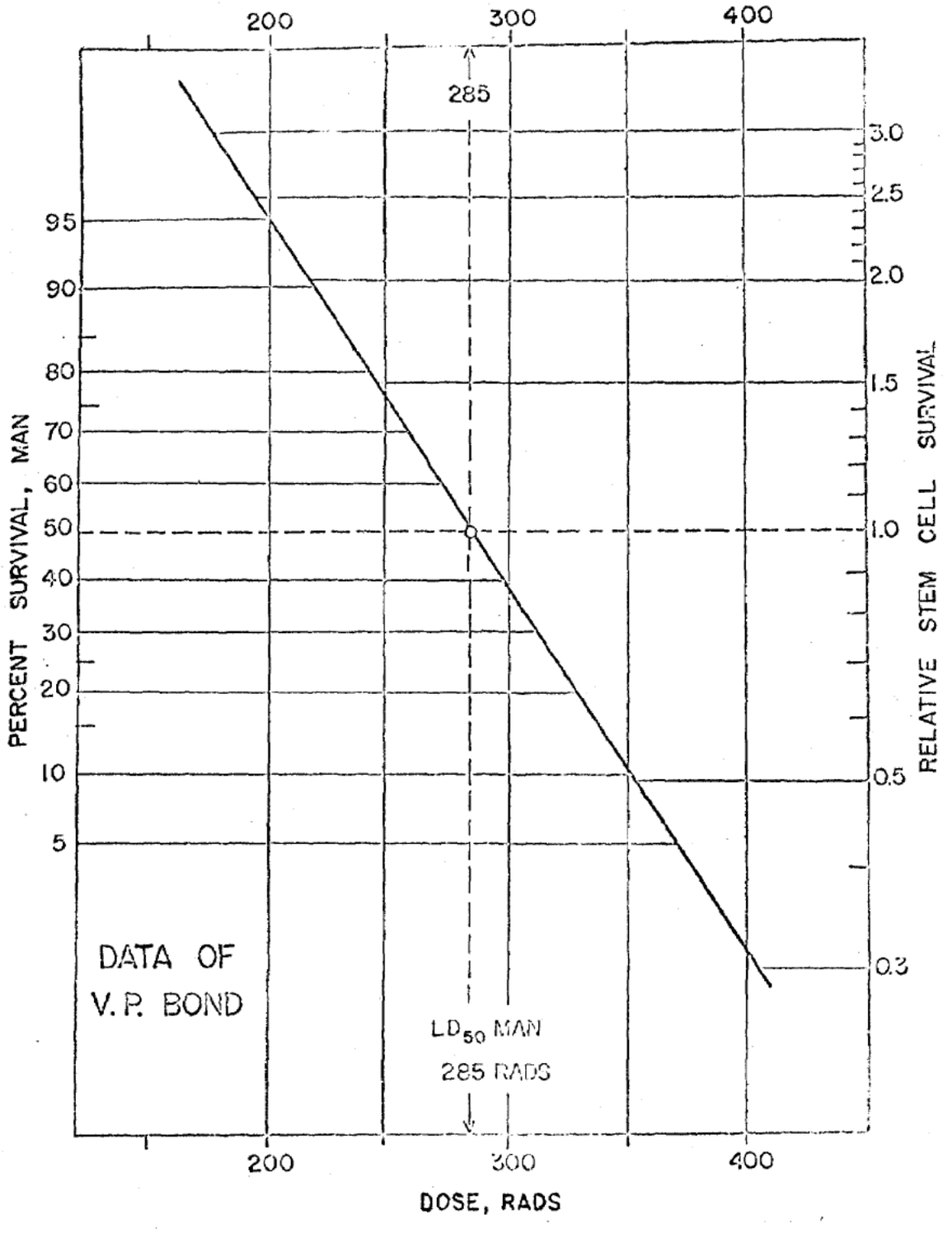
RELATIVE DOSES FOR ^{60}Co PARTIAL BODY (UPPER) IRRADIATION AS MEASURED WITH TL-100 POWDER AT CENTER OF RANDO PHANTOM LATERAL IRRADIATION.



[redacted]

[redacted]

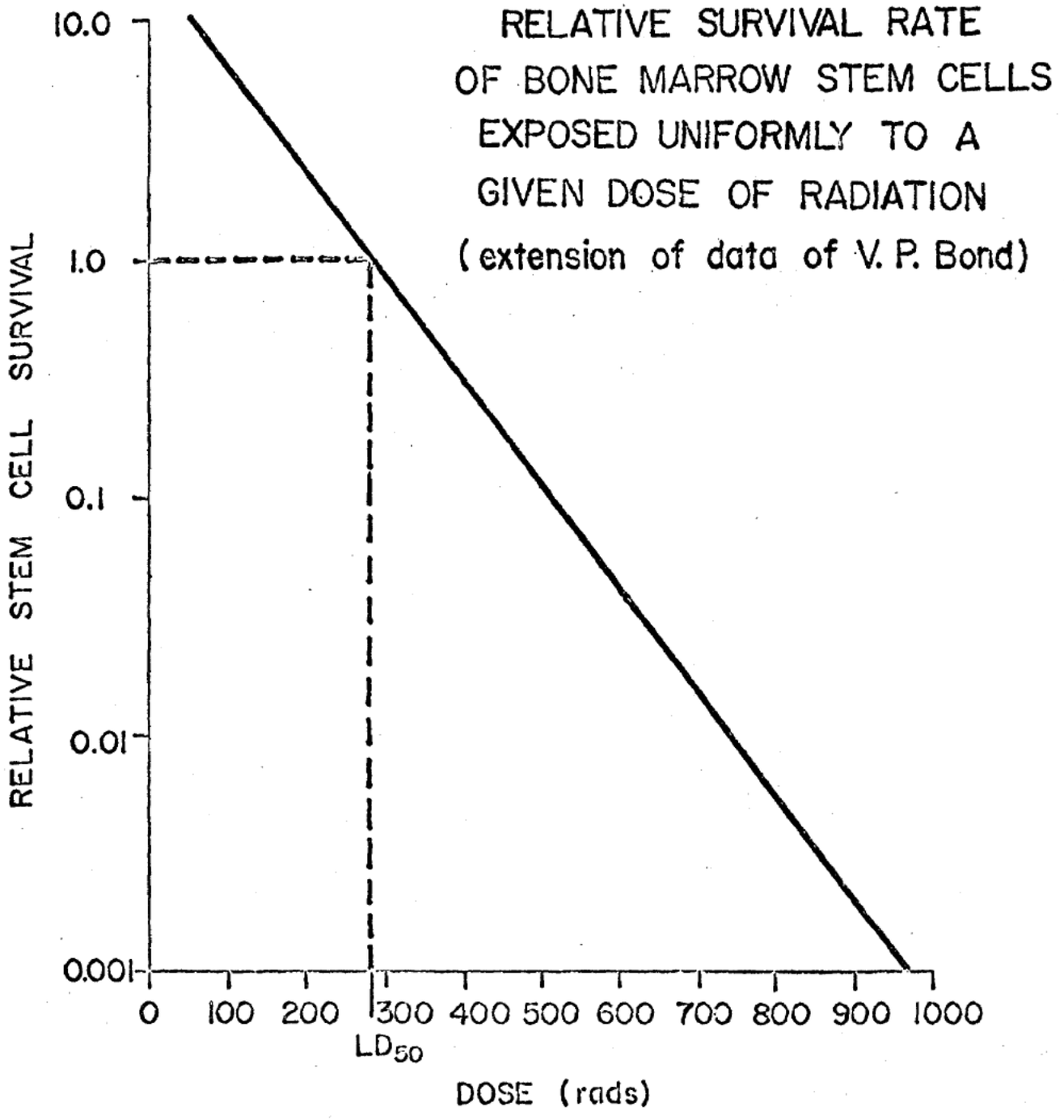
FIGURE 3



[redacted]

[redacted]

FIGURE 4


RELATIVE SURVIVAL RATE
OF BONE MARROW STEM CELLS
EXPOSED UNIFORMLY TO A
GIVEN DOSE OF RADIATION
(extension of data of V. P. Bond)
RELATIVE STEM CELL SURVIVAL
10.0
1.0
0.1
0.01
0.001
0
100
200
300
400
500
600
700
800
900
1000
LD50
DOSE (rads)

DISCUSSION

In reply to a query from Dr [redacted], Dr [redacted] said the 280 rad dose quoted was the mid-line tissue dose.

Dr [redacted] asked if the twin used for the marrow transplant was an identical one. Dr [redacted] confirmed this was the case.

Captain [redacted] asked what the status was of the 600 rad man. Dr [redacted] replied that he lost both hands and both feet.

AGENDA ITEM 9. EFFECT OF IONISING RADIATION ON COMBAT EFFECTIVENESS ([redacted])

Presented by Mr [redacted]

Herbert B. Gerstner, M.D. (Department of Radiobiology, USAF) reported in the Annual Review of Medicine, Vol. II 1960 that "radiation sickness" should be graded as mild, moderate and severe. Mild forms seldom appreciably impair physical and mental faculties, and therefore they are irrelevant to both radiotherapy and civil defence. Moderate forms however show marked weakness, anorexia, nausea and vomiting commencing between 2 and 4 hours after radiation. This phase lasts 5 to 8 hours and during this time, physical as well as mental capabilities are definitely reduced. This will be significant when it afflicts persons whose occupations demand full possession of physical and mental alertness, eg aircrews, executive officers, automobile drivers.

The severe form of radiation sickness causes complete incapacitation for 5 to 10 hours. This distinction of 3 grades is important for defence considerations.

General Research Objective

A study is to be made of the mental and physical effects of radiation in patients undergoing radiation therapy. An initial study would assess behaviour and response patterns. Dr [redacted] of the D.R.B., Toronto, would collaborate in the field of assessment of behavioural patterns.

Method

Each patient served as his own control. He was examined prior to receiving his radiation on the day of testing, and again at intervals of 2, 4 and 6 hours after the radiation treatment.

Clinical summaries included age, occupation, and level of education, history and diagnosis. Recordings were made of the amount of radiation given, pre and post irradiation symptoms, hematology when relevant, and results of psychological tests.

Test Methods - experimental psychologists at the Defence Research Board recommended a battery of tests known as Moran tests to be used to measure performance. The advantages of these tests are that in longitudinal studies, higher mental processes may be repeated daily, or even more frequently, without involving a learning process. The Moran tests are simple paper and pencil tests which are done in about 20 minutes.

DESCRIPTION OF MEASURES

A	Aiming - Measures ability to carry out quickly and precisely a series of movements requiring eye-hand co-ordination.	90 sec.
FC	Flexibility of Closure - Retention of specified configuration despite the influence of other distracting configurations in the perceptual field. (The specific configuration being sought is known.)	3 min.
NF	Number Facility - Addition of one or two-digit numbers in sets of three.	3 min.

PERCEPTION FACTORS

PS	I.	Perceptual Speed - measures speed with which subject can find a well known symbol in a mass of material.	2 min.
SC	II.	Speed of Closure - ability to unify an apparently disparate perceptual field into a single percept. (ie identify a class of object in a heterogeneous stimulus background).	2½ min.
V		Visualization - ability to visualize the contemplated outcome of objects manipulated in space.	3 min.

The order in which these tests were performed was varied with each patient ie a random selection of order was used in each case.

Each test had an instruction sheet which included a practice portion. The patients were asked to practice each test until they were confident in their ability to perform the test as quickly as possible.

These tests were all timed tests, using a stop watch for accuracy.

Subjects used were patients at The Princess Margaret Hospital in Toronto with neoplastic disease. They were selected for these studies because their general health was good, and the nature of the disease necessitated the irradiation of a large volume of tissue. The patients were also young; the average age of the 20 patients in the partial-body

[redacted]

[redacted]

radiation series was 37 years, with 13 patients being under 40 years. The primary diseases of the patients were as follows:-

Various Lymphomas	9 patients
Testicular tumour	7 "
Adult Wilms's tumour	1 "
Ca. Salivary gland with lung secondaries	1 "
Ca. Ovary	1 "
Squamous Cell Ca. of Rt. ear	1 "

The majority of the patients with lymphoma were suffering from Hodgkin's disease. The patients with testicular tumours had been referred for radiotherapy following surgical excision of the primary tumour.

Radiation

In all instances the radiation was carried out with one or other Cobalt 60 gamma ray sources. Usually a long source to skin distance was used to subtend the area being treated and unless indicated otherwise, one field was treated at a time. In some instances a specialised unit was employed with which it is possible to irradiate from the front and the back simultaneously. These details are to be found in the Table (Appendix I).

As can be seen only two patients were materially upset by the radiation and in both the radiation was directed to the abdomen which was the site of extensive involvement with lymphoma. In all other cases much larger doses were given to the same sites without producing constitutional upset.

Three patients were given total body radiation for variants of lymphomatous disease - the technique used is that of scanning a ceiling mounted Cobalt 60 unit backwards and forwards over the patient until the desired dose has been delivered. Half of the radiation is delivered from one side of the body and half the other (front and back) - the doses expressed are minimum midplane dose with a variation of ± 10%. The clinical course is summarised in Appendix II.

RESULTS

General Symptom Pattern

Two symptoms developed in all patients, namely fatigue and anorexia. These symptoms were slight at the 2 hour stage, ie 2 hours after irradiation, but they were most marked at 4 hours. By the 6 hour testing the majority of the patients were improved as far as fatigue was concerned, but they still complained of anorexia. Nausea was a symptom in 8 of the 20 patients, but was never severe or incapacitating. Vomiting was not reported.

Frequent symptoms were a feeling of "dullness" or "muzziness", and a feeling of depression or apathy. The patients complained that they had no desire to do anything but lie down and rest. They had to be encouraged to perform the tests, particularly at the 4 hour stage. By the 6 hour stage, most patients were more co-operative and more willing to make an effort to carry out any tests.

Results of Psychological Tests

An average result was obtained for the performance of each test at each time of testing by the 20 patients. These results are shown in table and graph form below.

Averages

	Pre radiation	2 hrs after	4 hrs after	6 hrs after
Aiming	96.8	101.2	103	101.8
Perceptual speed	57.3	60.9	61.2	61.9
Flexibility of Closure	8.4	9.4	10.2	10.9
Number Facility	32.2	34.6	35.3	36.1
Visualization	29.3	33.5	35.2	37.1
Speed of Closure	18.4	21.7	23.1	23.5

A general review of the averages obtained showed no deficit in performance of any one test. Each time each test was performed there was an increase in the number of correct results.

Conclusions

It has been shown that a dose of ionising radiation between 50 and 200 rads will produce some general constitutional symptoms in all patients. These are usually mild and consist of fatigue and anorexia insufficient to incapacitate the patient. Frequently there is also a degree of apathy or mental depression. Despite the fatigue and apathy, the 20 patients tested were able to perform the psychological tests with an increasing degree of accuracy on successive testings. This implies that there is a "practice effect" with these particular tests. The results of these tests indicate that either these tests are not sensitive enough to pick up minor changes in the patients' behaviour, or the amount of radiation received by these patients was not sufficient to cause detectable changes in their mental processes. Personal observation and impressions would tend to favour the first alternative; there were certainly some mild constitutional changes as a result of this radiation and one would speculate on similar slight changes in the patients' behavioural and response patterns. On the basis of this study and experience of total body radiation in the adjuvant management of Ewing's tumour, onecan say with considerable confidence that doses of 300 rads will produce a profound systemic upset if delivered in about 20-30 minutes, whereas up to 220 rads will not. We have been unable to find a clear cut dose correlation but it must be admitted that we do not have great experience of very low dose conditions.

Summary

A therapeutic dose of radiation between 50 and 200 rads tumour dose was given to 20 patients. All patients developed very mild constitutional symptoms of lassitude about 2 hours post-radiation, increasing in severity until 4 hours post-radiation and then rapidly improving. These symptoms were not accompanied by any deficit in performance of the Moran psychological tests, the patients having been tested until 6 hours after their radiation. The constitutional upset was not sufficient to interfere with work performance in most instances since the majority of patients were going about their daily routine. The testing was carried out after the first dose of radiation had been delivered in some instances and in others after the patients had become accustomed to the routine of their treatment plan in an effort to exclude psychological factors - however, there did not appear to be much difference in something that is so subjective as this.

[redacted]

APPENDIX I

Case No.	Region Radiated	Area of Field	Absorbed Dose at Max.	Systemic Symptoms
77708	Chest (Lymphoma) Front and Back Simultaneously	14 x 22 cm..	75 rads.	Nil
78418	Abdomen (Seminoma)	15 x 35 cm. Post field only	135 rads.	Nil
78209	Abdomen (Ca. Ovary) opposing fields treated simultaneously	25 x 25	Max. tissue 144 Min. - 140	Nil
78945	Abdomen (Seminoma) Anterior field only	12 x 35 Average	130 rads.	Nil
78857	Abdomen (Liposarcoma) Both fields treated simultaneously	15 x 30 cm.	200 rads.	Nil
78546	Abdomen (Hodgkins) Extensive intra-abdominal disease - anterior field only.	20 x 30 cm.	138 rads.	Nausea 2-6 hours post-radiation
78339	Abdomen (Adult Wilms) tumour	24 x 37 cm. Anterior field only	130 rads.	Nil
77321	Abdomen (Lymphoma) Anterior field only. Very extensive disease	30 x 36 cm.	63 rads.	Nausea 2 hours post-radiation
79053	Abdomen (Seminoma) Anterior field only	12 x 38 cm.	113 rads.	Nil
78410	Abdomen (Seminoma) Anterior field only	16 x 38 cm.	140 rads.	Nil

[redacted]

[redacted]

APPENDIX I (contd.)

Case No.	Region Radiated	Area of Field	Absorbed Dose at Max.	Systemic Symptoms
8111	Chest (Sec. from Salivary Gland Carcinoma) Both fields simultaneously	28 x 28 cm.	Max. 103 Min. 100	Nil
8092	Abdomen (Lymphoma) Anterior field only	20 x 40 cm.	67	Nil
8389	Chest (Sec. Testicular Ca.) Anterior field only	30 x 30 cm.	140	Nil
7713	Ear & Brain S.C. Ca. Middle Ear	5 x 6 cm.	334	Nil
8498	Abdomen (Ca. Testis) Anterior field only	13 x 35 cm.	140	Nil
8485	Chest (Hodgkins) Anterior field only	34 x 38 cm.	295	Nil
7584	Abdomen (Hodgkins) Anterior & Posterior field simultaneously	8 x 24 cm.	Max. - 235 Min. - 200	Nil
8329	Abdomen (Lymphoma) Anterior & Posterior fields simultaneously	18 x 35 cm.	Max. - 138 Min. - 132	Nil
7711	Chest (Lymphoma) Anterior field only	29 x 35 cm.	120	Nil
7574	Abdomen (Seminoma) Anterior field only	16 x 35 cm.	150	Nil

[redacted]

[redacted]

Appendix II

Three patients were given total body radiation. A man of 35 years of age with generalized lymphoblastic lymphosarcoma was given 20 rads twice daily as a total body scan; he had received 240 rads prior to day of testing. He was in very good general health. He did not develop any constitutional symptoms apart from mild nausea and fatigue. The psychological tests showed no deficit.

One 55 year old housewife (Patient B) with chronic lymphatic laukaemia with skin involvement was given 100 rads twice on one day, treatments being 8 hours apart. A 67 year old man (Patient C) with mycosis fungoides was given 100 rads twice on one day. These 2 patients developed marked fatigue and anoxeria 4 hours after their first radiation treatment; the fatigue was so severe that the first patient was unable to finish the last 2 psychological tests at this 4 hour stage. The second patient showed a slight deficit in performance of 2 psychological tests, at the same stage. At all other times of testing, there was no deficit in performance. As we had no more patients in this category, we were unable to randomize the order of the psychological tests, and it was therefore not possible to draw any conclusions from these tests.

Appendix II (contd.)

Patient B

Forms	Pre-Rad	2 hrs after	4 hrs after	2 hrs after	4 hrs	16 hrs
P.S.	50	45	50	45	49	50
S.C.	17	22	20	23	24	25
V.	10	12	21	21	24	19
A.	64	48	48	52	56	60
N.F.	41	43	29*	42	45	39
F.C.	5	2	2*	9	8	6
Nov. 30th						
Pulse	86	88	108	116	112	108
B.P.	110/60	116/68	110/60	125/60	125/65	118/60
HG	14.4	14.8	-	-	-	11.4
Total WBC	19.5	20.7	16.7	13.2	12.8	17.7
Polys	42	50	36	64	62	45
Lymphs	48	33	46	24	34	42
Platelets	150	160	Normal	Normal	Normal	Normal

[redacted]

[redacted]

Appendix II (contd.)

Patient C

Forms & Tests	Pre-Rad	2 hrs after	4 hrs after	2 hrs after	4 hrs	16 hrs
P.S.	53	48	50	50	46	50
S.C.	20	19	22	21	20	21
V.	35	25	31	27	27	32
A.	95	96	76*	90	88	94
N.F.	43	48	40*	45	47	45
F.C.	8	8	7	7	9	9
Pulse	84	110	96	100	106	86
B.P.	112/76	140/80	140/70	124/78	140/75	128/64
Hb	9.7	8.7	8.2	-	-	9.2
Total W.B.C.	8.9	9.7	8.0	7.4	6.4	6.4
% polys	63%	61%	60%	66%	59%	49%
% lymphs	34%	31%	34%	25%	29%	48%
Platelets	40	30	40	-	-	20

Jan 3, 1968

(after 2 bottles bld)

Hb = 6.9 W.B.C. = 3.5 Platelets <10

$\bar{c}$ 48% polys
40% lymphs

Jan 10,1968

Hb = 9.9 W.B.C. = 2.2 Platelets <10

(after 6 bottles bld) polys 29
lymphs 58

[redacted]

DISCUSSION

Dr [redacted] was of the opinion that Lushbaugh's 'epigastric rad' was invalid and that there is no epigastric 'centre of vomiting'.

Dr [redacted] asked what other factors would produce decrement. Mr [redacted] confirmed Dr Krohn's suggestion that fatigue would be an important factor. He said he would like to get information from the military on the times needed to carry out various combat tasks.

Dr [redacted] inquired whether tests at shorter times would show these decrements. Mr [redacted] said this was possibly the case.

Dr [redacted] asked if the irradiation had been to the head in any of the cases. Mr [redacted] replied that there was one such case.

Dr [redacted] asked if there were cases of nausea and vomiting. Mr [redacted] replied "no".

AGENDA ITEM 10. A REAPPRAISAL OF MAN'S TOLERANCE TO INDIRECT (Tertiary) BLAST INJURY (Robert K. Jones, D. R. Richmond and E. R. Fletcher, Lovelace Foundation for Medical Education and Research)

Presented by Dr [redacted]

Biological effects resulting from exposure to air blast have been arbitrarily divided into several categories, the most important of which are Direct (Primary), Indirect Missile (Secondary), and Indirect Whole-body Displacement (Tertiary).[1,2] Direct (Primary) damage is that associated with variations in environmental pressure per se. Such injuries generally occur where variation in tissue density is maximal, such as the sinuses, ears, lungs and gastroenteric tract, all of which contain a significant amount of air. Mortality from primary blast injury is generally due to severe pulmonary disruption with resulting dissemination of air emboli to critical vessels or asphyxia from intrapulmonary haemorrhage or edema.[3]

Indirect (Secondary) effects include those injuries resulting from the impact of penetrating or non-penetrating missiles, energized by blast pressures, winds, ground shock and gravity. Here anatomic localization of injury is not evident and death, in the case of mortal trauma, may result from a variety of causes such as blood loss from severe lacerations, infections from penetrating wounds of the abdomen or thorax, and, in some cases, crushing injuries can occur from the collapse of structures.

Indirect (Tertiary) effects include those injuries which result from actual displacement of the individual by winds, ground shock and gravity that accompany the pressure pulse. Damage may result during the accelerative or decelerative phase, but, in general, the latter is likely to be more important, particularly if impact occurs with a hard surface, and at lower pressure levels. In that regard, stopping distance following whole body displacement is of extremely great biological significance. The types of injuries associated with whole body displacement are those frequently observed as a consequence of automobile accidents,[4,5] falls,[6-8] and aircraft mishaps.[9,10]

Three distinct sets of information are required in order to properly establish hazards criteria for nuclear weapons blast effects. First, information concerning the alteration in environmental physical parameters must be understood as a function of range, yield, height of burst and type of device, both in free-field and within various types of inhabitable structures. Second, one must understand how such alterations in physical parameters influence objects the size and shape of man. (For example, it is essential to know what translation velocities might be attained by man as a function of peak pressure and pressure duration.) Finally, one must understand the frequency, nature and relative significance of injuries which result from blast wave parameters of various magnitude. Blast biology studies performed at Lovelace Foundation over the past 17 years have been designed to provide the physical and biological data necessary for the

formulation of realistic hazards criteria. Since the major effort has been directed toward primary blast injury, the reliability of current primary blast hazards criteria, published by Bowen et al.[11] based on studies involving thirteen animal species, is considerably greater than that currently available for secondary and tertiary blast effects. Recognizing that whole body translation represented one of the more far-reaching hazards, particularly in regard to large yield nuclear weapons, and since the uncertainties are perhaps greatest in this area, it appeared prudent to re-appraise our tentative hazards criteria for indirect (tertiary) blast effects.

Pertinent Translational Impact Studies:

Information concerning velocities attained by objects the size and shape of man, in relation to the physical parameters of the blast wave from nuclear explosions, were collected by several investigators (Butterfield and Seager; [12] and Taborelli et al. [13]). In 1961 Bowen and his co-workers, [14] using empirical data available at the time, refined a mathematical model for predicting the time displacement history of objects as large as man when energized by blast pressures and winds from high-yield explosions. Unfortunately, very meagre quantitative biological information was available at the time relative to the consequences of decelerative impact for either humans or other mammals. Not only was this true for impact with solid objects but even greater uncertainty was prevalent in regard to the relative hazard of decelerative tumbling.

A study was therefore initiated which addressed itself to the problem of mortality as a function of impact velocity. [15,16] A total of 455 experimental subjects representing four animals species, mice, rats, guinea pigs and rabbits, were dropped from various heights so that impact velocities from 24.8 to 50.9 were attained. All animals were dropped in a prone position so that impact with a concrete pad also occurred in this orientation. Twenty-four hour mortality data was obtained for each animal species over a range in lethality from near zero to 100%. These empirical data were applied to a probit analysis in order to obtain an expression for mortality vs. impact velocity for each animal species (Table 1). The interspecies relationship between impact velocity associated with 50% mortality for the mouse, rat, guinea pig and rabbit, and average mass of the species was examined using the method of least squares. This regression relationship was then used to predict the LD_{50} impact velocity for a 70 kilogram mammal (ie, man) and proved to be 26 ft/sec (Graph 1).

Although grave uncertainties were recognized and expressed by the authors of this paper in regard to the predicted LD_{50} impact velocity of 26 ft/sec for a 70 kilogram animal, certain other information available at the time appeared to lend credence to such predictions. Examination of the National Safety Council's statistics [17] relevant to fatalities in urban automobile accidents placed the LD 50 near 23 miles per hour or 34 ft/sec.

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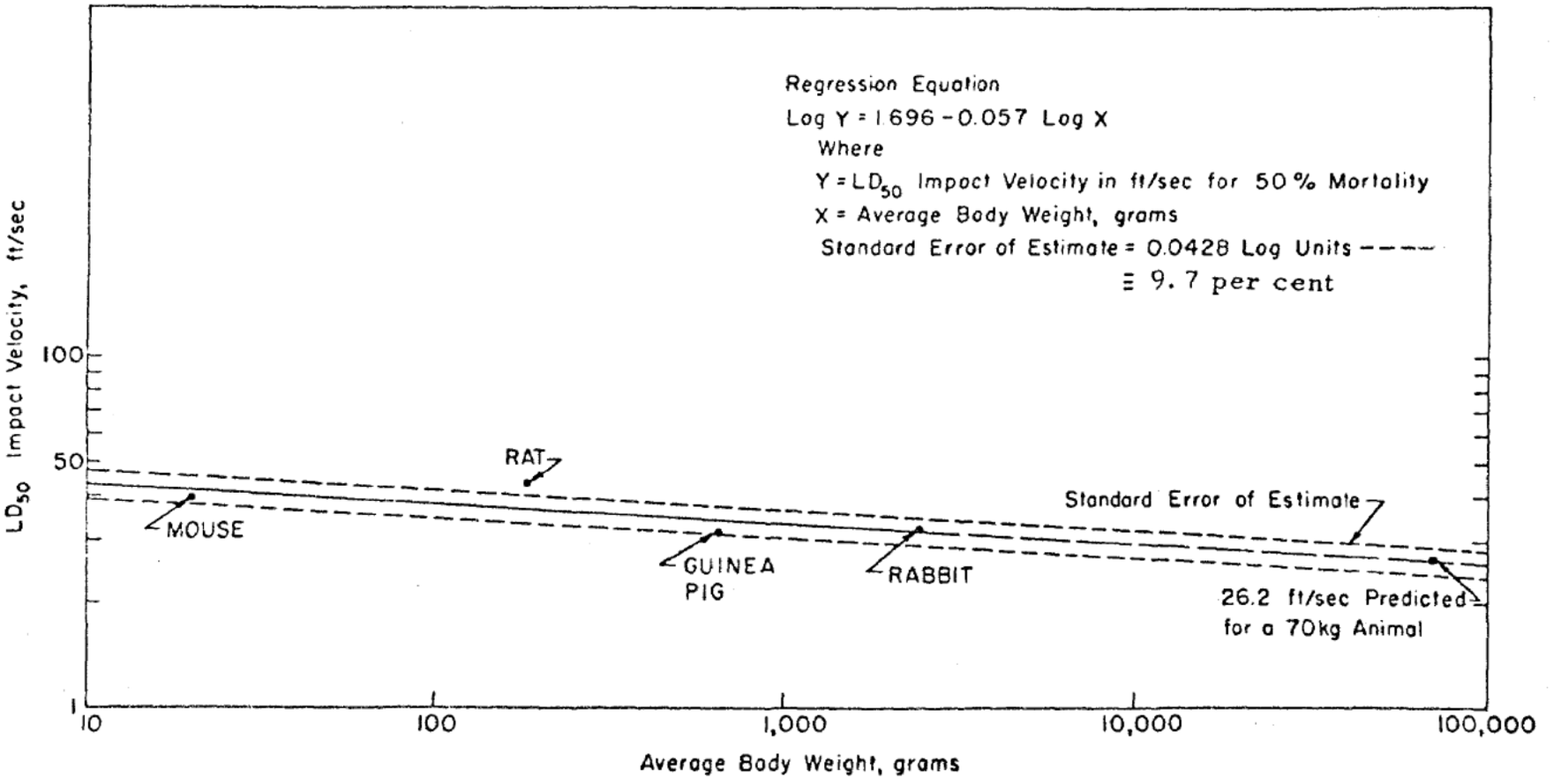
GRAPH 1

IMPACT VELOCITY ASSOCIATED WITH 50 PERCENT MORTALITY
AS A FUNCTION OF AVERAGE BODY WEIGHT*



GRAPH 1

*Data taken from references 15 and 16.

However, this velocity represented the speed at which the accident occurred and it was uncertain whether this represented the actual velocity at which a fatally injured person struck a solid surface. Although it was recognized that this apparent correspondence might be more fortuitous than real, it was felt that under the circumstances, the predictions might be used for purposes of testing this extrapolation and, in certain other circumstances, since nothing better was available at the time.

It was further recognized that the design of the experiment minimized random orientation at time of impact, and that righting reflex and the legs of the animals might result in a decrease in the velocity of contact of the main mass of the body. Further, direct trauma to the calvaria was markedly reduced by the prone orientation of the experimental subjects. Both of these factors might result in reduced mortality and unrealistically high LD_{50} impact velocities.

TABLE 1

RESULTS OF PROBIT ANALYSIS RUN ON IMPACT DATA
(PERPENDICULAR IMPACT WITH A NON-YIELDING SURFACE) *

Species (Number dying/ number exposed)	Mean Body Mass kg	Impact Velocities in ft/sec Resulting in 1,50, and 99% Mortality (with 95% confidence limits)		
		V_1	V_{50}	V_{99}
Mouse (44/113)	0.0198	30.0 (28.1, 31.5)	39.1 (37.8, 40.4)	50.9 (48.4, 54.5)
Rat (90/178)	0.185	33.4 (31.2, 35.1)	43.6 (42.4, 44.7)	56.8 (54.4, 60.2)
Guinea Pig (57/111)	0.650	23.7 (22.2, 24.9)	30.9 (30.0, 31.9)	40.3 (38.4, 43.0)
Rabbit (26/53)	2.43	24.3 (22.6, 25.8)	31.7 (30.4, 33.2)	41.4 (39.1, 44.6)

*Data taken from references 15 and 16.

The work of Black et al.[18] and Draeger et al.[19] on human accident victims and cadaver skulls, respectively, showed that skull fracture could result from a blow with an average velocity of 15 ft/sec. Gurdjian et al [20] reported experiments in which forty-six cadaver heads were dropped on a

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solid surface where the minimum impact velocity necessary to produce a fracture was 13.5 ft/sec. Although impact velocity necessary for skull fracture was investigated, predictions for serious intracranial consequences of head injury, such as concussion, were less certain. In regard to this, Zuckerman and Black[21] using monkeys failed to produce signs of concussions or fracture with "initial" velocities of 10 ft/sec. This was true whether the animal's head was strapped facing the plate or away from it. These studies all indicated the importance of body orientation at impact, and the vulnerability of the skull in any consideration of mortality as a function of impact velocity. The consistency between British and American data placing the threshold for skull fractures at near 13 ft/sec. resulted in some confidence that an impact velocity with a hard flat surface of 10 ft/sec should prove to be acceptable for the head of an adult man.[18]

Impact velocities, associated with other types of osseous fractures, were also studied by a number of British and American investigators [18, 19] and again a remarkable consistency of data resulted in spite of the markedly different methods employed. These studies showed that impact velocities much above 11 to 12 ft/sec could produce osseous fractures.

Finally, studies by Swearingen et al.[22] in which thirteen adults were subjected to drop tests in a track-guided chair, which travelled vertically downward to impact against a platform, showed that a 10 ft/sec impact velocity was the maximum tolerated by such human volunteers. Although such impact velocities resulted in no discernable injuries, they were associated with pain of variable severity, referable to various parts of the body.

Utilizing information from these experiments, tentative biological criteria were formulated for estimating blast hazards due to whole-body displacement[23] (Table 2). Appropriate reservations were duly noted pertaining to the tentative nature of these estimates and, in addition, a plea was made for additional animal experiments and for the collection of additional human accident data.

TABLE 2

TENTATIVE CRITERIA FOR INDIRECT (TERTIARY)
BLAST EFFECTS INVOLVING IMPACT

Condition Critical Organ or Event	Related Impact Velocity ft/sec
Standing Stiff-Legged Impact*	
Mostly "safe"	
No significant effect	< 8 (?)
Severe discomfort	8 - 10
Injury	
Threshold	10 - 12
Fracture threshold (heels, feet and legs)	13 - 16
Seated Impact*	
Mostly "safe"	
No effect	< 8 (?)
Severe discomfort	8 - 14
Injury	
Threshold	15 - 26
Skull Fracture+	
Mostly "safe"	10
Threshold	13
50 per cent	18
Nearly 100 per cent	23
Total Body Impact++	
Mostly "safe"	10
Lethality threshold	20
Lethality 50 per cent	26
Lethality near 100 per cent	30

* Data from Draeger, Barr, Dunbar Sager and Shelesnyak; Black, Christopherson and Zuckerman; Swearingen, McFadden, Garner and Blethrow; Hirsch; and Eiband.
\+ Data from Gurdijian, Webster and Lissner; Zuckerman and Black.
++ Data from Richmond, Bowen and White.

A Consideration of Additional Relevant Data:

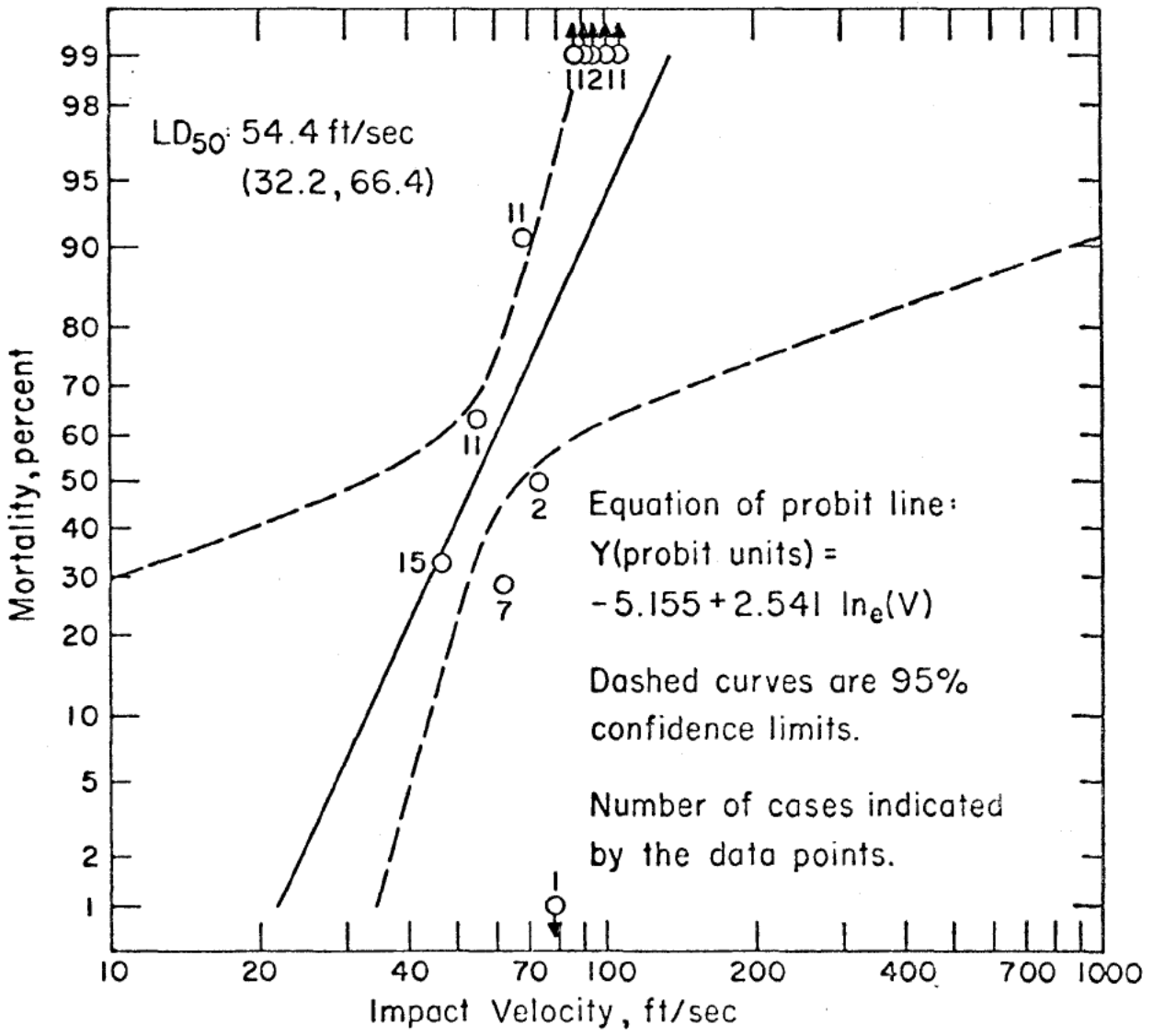
In order to understand better the potential relationship between body mass and impact velocity as it might relate to LD_{50} values for impact with a solid surface, drop studies were performed at Lovelace Foundation utilizing dogs with an average body mass of 18 kilograms.[24] A total of twenty-nine animals were dropped from heights ranging from 10 feet to 45 feet, representing impact velocities of from 25.2 to 53.6 ft/sec. All animals were dropped in such a fashion that impact occurred on a rigid flat surface in a uniform feet first position. Although the total sample number was limited, the data were treated utilizing probit techniques to prepare probit mortality curves as a function of impact velocity. The tabular data are shown in Table 3. An inadequate sample size was exposed at both high and low impact velocities to enable one to establish very close confidence limits. The important feature, however, is that the impact velocity predicted for an LD_{50}, in the case of 18 kilogram animals, appears to be well above 50 ft/sec which is a factor of two higher than would be anticipated utilizing extrapolations from the previous small animal experiments.

Shortly after the temporary cessation of these larger animal experiments, an article appeared by William S. Lewis et al.[8] entitled "Jumper's Syndrome, the Trauma of High Free-Fall as seen at Harlem Hospital." These authors described the consequences of such falls in fifty-three individuals ranging in age from 1-1/2 to 66 years. Mortality and injuries were listed as a function of height of fall, but were grouped by the height in stories from which the falls occurred. Unfortunately, no information was given in terms of injuries or mortality for individual cases. Mr I. G. Bowen, recognizing the potential value of this study in arriving at human LD_{50} values for vertical impact on a hard surface, prepared a probit plot of percent mortality against impact velocity (Graph 2). In this manner he arrived at an LD_{50} of 54 ft/sec with 95% confidence limits of 41 to 64. Table 4 shows the tabular data from this analysis. Because of the relatively few cases occurring at the 1 and 99% mortality levels, the confidence limits were considerably broader in these mortality ranges. By considering the age distribution of the individual cases, he arrived at a mean body mass of approximately 50 kilograms. An attempt was made to obtain individual case history reports in order to examine more adequately the relationship between impact velocity and the types of severity of non-fatal injuries. Unfortunately, these records were not available.

GRAPH 2

53 Human Free-Fall Cases from Lewis et. al., 1965*

(Impact with concrete)



*Data taken from reference 8

TABLE 3

RESULTS OF PROBIT ANALYSIS RUNS ON IMPACT DATA
(PERPENDICULAR IMPACT WITH A NON-YIELDING SURFACE)*

Species (Number dying/ number exposed)	Mean Body Mass kg	Impact velocities in ft/sec Resulting in 1, 50 and 99% Mortality (with 95% confidence limits)		
		V_1	V_{50}	V_{99}
Dog (5/29)	17.6	25.4 (7.16, 34.5)	64.3 (50.0, 146)	163 (94.3, 2280)

*Data taken from reference 24.

TABLE 4

RESULTS OF PROBIT ANALYSIS RUN ON 53 HUMAN FREE FALL CASES
(IMPACT WITH CONCRETE SURFACE)*

Species (Number dying/ number exposed)	Mean Body Mass kg	Impact Velocities in ft/sec Resulting in 1, 50 and 99% Mortality (with 95% confidence limits)		
		V_1	V_{50}	V_{99}
Man (31/53)	50	21.5 (2.73, 32.7)	54.4 (40.9, 64.2)	136 (95.6, 811)

*Data taken from reference 8.

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[redacted]

If one examined the results of probit analysis run on the impact data, a species grouping is seen similar to that observed in the case of primary blast injury. The large animal species, dog and man, appear to be considerably more tolerant than the small animal species. Thus, it is apparent that the median lethal impact velocity for man impacting on a flat non-yielding surface, is considerably higher than the tentative estimates previously based on extrapolation from four species of small animals. This number appears to be somewhere near 50 ft/sec, based on the human vertical fall data from Harlem Hospital. Although this number may be better than the previous tentative estimate of 26 ft/sec, it too should be treated with a great deal of scepticism for the following reasons: (1) Body orientation at impact following a free-fall can in no way be considered to occur in a random fashion. As pointed out by Snyder, 60% of a total of 129 human free-fall cases impacted feet first whereas only 15% of this population were orientated head first. This would tend to minimize cerebral trauma and would result in higher predicted LD_{50} impact velocities than might occur with random orientation. (2) The population studied included cases with an age distribution from 1-1/2 to 66 years and the probit was based on the entire population. Since the effect of age on impact tolerance has not been adequately investigated, this too introduces additional uncertainties. (3) Impact tolerance may also vary as a function of sex or physical condition and mass of the individual and neither of these factors were considered in this analysis.

The physical factors which influence injury or mortality for human impact due to whole body displacement from blast winds must also be appreciated. Human tolerance would, in all probability, be considerably higher in cases where impact occurs on a yielding surface where deformation is possible more so than would be the case for impact against a rigid non-yielding surface. Similarly, the distribution of force on the impacting object would be different for sharp angular surfaces as opposed to that which would occur against flat surfaces and such differences could greatly influence impact tolerance by producing dissimilar traumatic injuries. Finally, in addition, the magnitude of the force and the time duration of impact are also physical parameters which greatly influence human impact tolerance.

Thus far only the case for whole body impact against a rigid surface has been considered. The problem of human tolerance for decelerative tumbling following whole body displacement is even more perplexing. Considerably less experimental animal data is available than in the case for whole body impact and virtually no human experience is at hand to test the validity of extrapolations made from animal data. In preparing tentative criteria for human tolerance to decelerative tumbling, two animal experiments were utilized. In the first study by R.S. Anderson et al. 25 goats were tumbled to a stop over a grassy pasture after being accelerated by winds produced by an open ended shock tube. Five of the nineteen goats attaining velocities of from 54 to 78 ft/sec did not survive. Because of the limited number of animals and the rather narrow velocity range, a

probit slope could not be accurately estimated from the data. For want of a better approach, the common probit slope of dog and man for perpendicular impact was assumed in deriving the velocities shown in Table 5. The very broad 95% confidence limits should be duly noted, indicating the grave uncertainties for tolerance to decelerative tumbling.

In a second experiment, also illustrated in Table 5, two dogs and four sheep were released from a truck travelling at 88 ft/sec over a smooth dirt road.[26] The animals were unanaesthetized and held approximately one foot above the ground at release. In several instances, documentary movies revealed that the animals actively participated in the tumbling thus perhaps minimized serious injury. Although some of these animals would probably be considered casualties, one case of a fractured orbital ridge, one with fractured teeth, andtwo with deep lacerations, there were no deaths. Thus, for the above consideration, the velocity required to produce 50% mortality must be well in excess of 88 ft/sec.

However, it should be noted that there were essential differences in these two experiments. In the case of the nineteen goats, the animals were anaesthetized and therefore could not actively participate in the tumbling. Some impacted with the end of the tube and in somecases were lofted at least 6-1/2 feet above the ground as they left the shock tube. Based on photographic coverage of displacement of two goats on Operation Snow Ball, [27] lofting of this degree did not take place at over-pressure levels similar to those used in the Anderson study. Further, the accelerative phase occurring in the shock tube experiment might have possibly contributed to the observed injuries. In the Lovelace experiment the animals were unanaesthetized and did not experience the accelerative phase seen with blast-induced displacements. The relative significance of these differences as they might affect the observed results must remain a matter for conjecture but it is clear that each could be extremely important.

From this rather cursory review of literature pertinent to the blast displacement problem, it should be readily apparent that there still exists inadequate information to prepare realistic human hazards criteria for tertiary blast injury. Although we feel that the current human LD_{50} estimates of 54.5 ft/sec for whole body impact with a non-yielding surface and 80.4 ft/sec for decelerative tumbling are more realistic than previous estimates, there still remain grave uncertainties. Any significant improvement in these numbers will require a considerable amount of new information.

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TABLE 5

RESULTS OF PROBIT ANALYSIS RUN ON IMPACT DATA
(DECELERATIVE TUMBLING OVER THE GROUND)

Species (Number dying/ number exposed)	Mean Body Mass kg	Impact Velocities in ft/sec Resulting in 1, 50 and 99% Mortality (with 95% confidence limits)		
		V_1	V_{50}	V_{99}
Goat * (5/19)	36.7	31.7 (7.42, 44.7)	80.4 (62.0, 158)	203 (121, 2380)
Dog ** (0/2)	22		$\lesssim$ 88	
Sheep (0/4)	52		$\lesssim$ 88	

* Data taken from reference 25.
** Data taken from reference 26.

Ideally one would like to have additional well-documented case histories on human impact victims with special reference to:

1. Impact velocity
2. Orientation at impact
3. Age
4. Sex
5. Nature of the impact surface
6. Nature and severity of injuries sustained both for survivors and non-survivors
7. Weight and physical condition

[redacted]

[redacted]

However, since such data are difficult to accumulate and impossible to obtain for certain configurations of exposure, one would also like additional animal data to determine:

1. Impact velocity LD_{50} as a function of species mass.

2. Effect of orientation at impact on survival and injury type.

3. The relative importance of the accelerative phase of blast-induced translational injury, particularly in regard to decelerative tumbling.

4. The relationship between threshold mortality impact velocities and injuries producing combat ineffectiveness.

5. Displacement hazard in various fortifications and within other types of structures.

Finally, it is necessary to obtain certain physical measurements such as:

1. The blast environment within structures as it might relate to translational injury.

2. Blast displacement of prone dummies to improve the translational model.

The discouraging feature of this review is that we are currently only a little better off then we were in 1961 when the four species small animals experiments were performed in regard to human impact tolerance. Although these current values may be unrealistically high, this is the price that man must pay for his ignorance.

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DISCUSSION

Lt Col [redacted] remarked that the primary interest lay in incapacitation. Dr [redacted] said there was insufficient information available, the LD might be associated with 50% combat ineffectiveness.

Dr [redacted] asked if Dr [redacted] was satisfied that velocity was the correct variable, in road accidents acceleration or deceleration was the governing factor. Dr [redacted], replying, said that fresh heads were used for the determination and the results obtained in ft/lbs. It was difficult to know how you applied 'G' to damage to organs, eg liver, spleen etc. They therefore replotted the head data in terms of impact velocity; it was hard to find a better parameter than this. In battle conditions it was unlikely that impacts would be with soft surfaces, the only cushioning therefore would be by tissue and this could vary, eg accelerometers screwed to different parts of the chest would all give different readings. He had spoken to State Police because they were trained to evaluate accident situations and to estimate the velocity of impact. Dr [redacted] said that the clothing worn would give different results. Dr [redacted] said that in auto accidents the speed of the car did not necessarily give the speed of impact, furthermore, the speeds were only estimates.

Dr [redacted] asked if the St Louis survey was complete. From his own experience information derived from hospital data was highly selective, it neglected those who are killed and those who walk away. Dr [redacted] said they had been unable to satisfy themselves on this point. Dr [redacted] suggested that they should distinguish between hospital and mortuary cases. Dr [redacted] inquired if consideration had been given to the establishment of a registry for such cases. He felt the data should be available for a prospective survey. Dr [redacted] said he had asked the Armed Forces Explosives Safety Board for information but so far they had had no co-operation. Dr [redacted] said that this was a constant problem. The Chairman asked if the Panel should set this in train. Mr [redacted] said that he knew of one hospital which would be extremely interested in providing this information, furthermore many organisations already had study groups for highway accidents. Mr Rittenbury went on to ask if, in the case of head injuries, whether ECG's were carried out. Dr [redacted] replied "no".

The Chairman suggested that they record in the actions "That each country attempt to collect and co-ordinate data on accidents". This matter was referred for discussion later in executive session.

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AGENDA ITEM 11. CURRENT EVALUATION OF LONG RANGE PLANNING FOR MEDICAL NUCLEAR WEAPON EFFECTS RESEARCH

Presented by Lt Col [redacted]

Introduction

The DASA Medical Nuclear Weapons Effects Research (NWER) Programme is formulated and administered in response to Research Requirements (Requ) submitted by the Defense Agencies and the Services. These Requ are consolidated, evaluated in the DOD priority system and discussed at our annual Long Range Planning Meeting.

Subsequent research proposals from Service Laboratories, Educational Institutions, Research Foundations and commercial firms are reviewed by Dr Stark and his Medical Directorate. Then they are formally discussed and further evaluated by the Medical Advisory Group for DASA funding.

Long Range Objectives

To define and evaluate human response and vulnerability to the effects of nuclear weapons and to prevent, mitigate or delay that response through improved understanding of the mechanism of injury and advances in prophylaxis, diagnosis, prognosis and treatment of the three basic injuries produced (radiation, blast, burn) and the many variant degrees and combinations that would occur in the free and non-free field environment. Detailed human response data will then be used in assessing man's limitation in relation to weapon systems vulnerability and the Strategic/Tactical doctrine for their employment.

Present Research Programme

The DASA programme utilizes a variety of simulated sources: Pulsed Reactors (Triga/Godiva), Neutron Generators, X-ray machines, ^{60}Co sources, Accelerators, Flash Burn Arrays, Shock Tubes, White Light Flash Sources and Lasers, all in conjunction with standard and advanced biomedical laboratory equipment. Several animal species are used to evaluate varied end points and wherever possible data are acquired directly from man.

The Programme is subdivided into 5 TASK areas:

a. Incapacitation, performance decrement and combined injury;

b. Oculo-thermal injury;

c. Radiation injury;

d. Biophysics of radiation injury;

e. Analysis and application of biomedical data.

[redacted]

I will briefly discuss some aspects of our higher priority Incapacitation/ performance decrement and Oculo-thermal programmes.

a. The Incapacitation/performance decrement Programme involves three human cancer therapy studies and is attempting to evaluate the dose-time-effect of radiation on man as it relates to sensory, psychologic, perception, co-ordination, discrimination and memory functions. Exposures are total and partial body with ^{60}Co.

Three laboratories are evaluating the effect of pulsed radiation on trained animal response. Primates are the principle subjects, however miniature swine and beagles have also been studied.

(1) The first order of business was to evaluate the dose-rate and neutron/gamma ratio differences of the two pulse reactors in order to determine if they were, in fact, comparable simulation sources for the performance decrement end points of interest. Primates trained to the same task were exposed to a 6:1 neutron/ gamma ratio in 50 μs and others exposed in 50 ms. We saw no appreciable difference in performance response. One limited pilot study compared exposures administered in 50ms consisting of a 6:1 and a 1:6 neutron/gamma ratio; no statistical difference was observed, however additional research in this area is indicated.

(2) Chaired and free (un-fettered) primate experiments are continuing and it is interesting to note that although the Early Transient Incapacitation (ETI) (also referred to as a severe transient Performance Decrement) is observed shortly after irradiation in both cases. However in the free animals, the time to onset of Permanent Complete Incapacitation (PCI) is five times as long as for the chaired subjects.

(3) Head and trunk shielded studies are in progress and multiple prompt exposures will begin this spring. Dose separation times will vary from 30 minutes to 6 hours.

(4) A summation of several different primate experiments showing per cent of animals incapable of any purposeful action at the listed post response times is listed below. No task complexity correlation was attempted and the percentages are specific for the time given and are not additive. They may decrease temporarily due to varying recovery from ETI before onset of PCI.

[redacted]

[redacted]

Dose	At 15 mins.	At 1 hour	At 4 hours	At 8 hours
2,500r	25 (44) *	25 (69) *	33 (67) *	17 (67) *
5,000r	56	56	33	50
10,000r	67	67	67	67

*Where survival depends on continuous performance, the percentage increases dramatically, see parentheses above.

b. The Oculo-thermal Programme also uses trained primates to evaluate the effect of retinal burn on visual acuity. School of Aerospace Medicine (SAM) had published a Safe Observer prediction model for retinal burn (RB) and recently acquired primate threshold burn data are being incorporated with a retinal time-temperature-history calculation in order to predict for the high altitude case. Flash blindness research is continuing for high intensity, short duration flashes and multiple flash exposures. A prediction model has been formulated which will assess the sky brightness contribution to flash blindness.

FY 71 REQUIREMENTS:

The consolidated NWER Requirements specify a need for additional information on:- Radiation exposure response, Oculo-thermal effects, Diagnosis and prediction, Shielding/Partial body studies, Prevention and therapy, Combined effects and personnel dosimetry.

a. DASA has been requested to support research to provide dose estimates which will cause 50% Combat Ineffectiveness 5, 15 min, 1, 4 and 8 hrs at five post exposure times when persons are exposed total or partial body to radiation doses delivered acutely, fractionated and continuous. Further information is desired on the effects at the cellular, organ and system level and their subsequent recovery rates. Chemical and/or shielding protection studies have been requested and the determination of the Relative Biological Effectiveness (RBE) for high Neutron Spectra were specified.

b. The following Oculo-thermal requirements were identified:

(1) determine permanent injury threshold energy levels for the eye as a function of delivery rate and image size for flashes less than 165 microseconds;

(2) establish flash blindness recovery times as a function of rate for flashes less than 500 milliseconds;

(3) determine cellular sensitivity of various portions of the retina;

(4) select and study protective drugs which will decrease flash blindness (FB) recovery times;

(5) determine delayed and chronic effects from high intensity flashes.

c. The requirement for Combined Injury or Integrated Effects data encompasses the three nuclear stresses (Blast, Thermal and Radiation) associated with a variety of other injuries and stresses.

(1) Data specifically requested were radiation, burn and wounds, radiation and infection, radiation plus chemical agents and radiation and environmental stresses.

(2) Detailed behavioural information following acute exposure to radiation, blast and thermal were requested as well as behavioural changes resulting from fractionated and continuous doses of low rate radiation.

d. A requirement exists for additional free field translation data, and non-free-field transmission translation and reflection information. Multiple burst effects data are sorely lacking.

DASA PLANS:

DASA will continue the PD research on Dose-time-response using trained primates and available human data. Total body studies will be pursued using single and multiple doses. Partial body exposure and mechanism of injury studies will be suggested. We will be unable to address the eight task, five post exposure time, three dimensional matrix in its entirety, however applicable data will be collected and applied where possible.

DASA plan to complete research on RB injury thresholds for short duration flashes and evaluate flash blindness recovery times as a function of rate. We will update the existing RB model with high altitude weapons output, primate data and adding Time-Temperature-History calculations. In FY 70, normal human FB recovery and multiple flash studies will be completed. DASA feels sufficient data exists to define the eye cellular sensitivity.

We will NOT be able to support research on chemical-drug improvement of FB recovery nor the delayed or chronic effects of high intensity flashes.

DASA plans to continue support in the Blast and Combined Injury Area. Studies on Radiation and Infection and Immunoligical alterations will continue to be pursued. Fund limitations preclude combined effects studies on fractionated or continuous low dose rate radiation at this time.

DISCUSSION

Mr [redacted] asked if any work was in progress on chemical agents which would reduce retinal bleaching. Dr [redacted] replied that there was a feasibility study in train on this subject.

Dr [redacted] asked if by 'visual acuity' this was actually what was meant. Col [redacted] replied that measurements were actually made of resolving power.

Mr [redacted] asked if laser sources were used. Col [redacted] said they were mostly white light sources, although neodymium, argon and CO_2 were also used. Dr [redacted] said that whether the light was coherent or not had no influence.

Dr [redacted] inquired as to how the animals died, when, and whether they were all CNS deaths. Col [redacted] said no, they experienced terminal depression and did not respond. At the moment they were looking at shock and drop in blood pressure with resulting falls in cerebral blood flow. Dr [redacted] said that with 2,500 to 10,000 rad cardio-vascular deaths occurred. Dr [redacted] confirmed that there is a sharp drop in blood pressure and quite a few cardio-vascular deaths. Dr [redacted] asked if there was pulmonary oedema with haemorrhage as described by Mathé. Col [redacted] replied that this did not occur in the early time frame at high doses.

AGENDA ITEM 12. WOUNDS AND DECONTAMINATION

Presented by Dr [redacted]

Contamination of the skin has been very well reviewed in a number of places. Attention is particularly drawn to the description in the Code of Practice for Use in Hospitals and to the review published as Radiation and Skin AHSB (RP) R.39 edited by E. R. Wray and available from HMSO price seventeen shillings.

Contaminated wounds present a more specific problem and may create a potential hazard, both at the site of the wound and for the critical organ by the particular material. Because of its very small maximum permissible body burden, plutonium presents a special difficulty. Much of the published information on plutonium toxicity is derived from intravenous injections of plutonium citrate. In practice wound contamination, even with a "soluble" substance like plutonium nitrate, tends to behave differently. There is a quick initial release to the circulation and the remainder of the material behaves in a colloidal fashion. In consequence early excision of the wound in a bloodless field is theprocedure of choice and, similarly, if chelating therapy by DTPA is to be introduced it has to be promptly started.

It is suggested that a dose of 0.1g of DTPA is quite sufficient in the vast majority of cases and that a dose schedule covering only the first few days is probably as useful as a more prolonged regime of therapy.

Three recent small wound cases from Windscale are reviewed by G. B. Schofield at the forthcoming Vienna conference and five conclusions can be derived from these.

a. All wounds are different and must be treated on their merits.

b. The amount of plutonium transferred to the rest of the body is only a few per cent of the original deposit at the wound site.

c. In these small wounds surgical excision is very effective in removing the plutonium at the wound site and the use of bloodless fields with local anaesthesia is recommended.

d. Animal experiments show that the most effective removal of plutonium from the body is obtained when DTPA is injected as soon as possible after the wound contamination. Experience from these three wound cases supports this general conclusion.

e. There was no indication that 1g of DTPA was more efficacious in removal of plutonium from the body into the urine than injections of 0.1g. The higher amount is, however, advisable in those cases where the excision cannot be carried out for several hours after the wound has occurred.

[redacted]

DISCUSSION

Dr [redacted] inquired if there was any benefit obtained by blocking excretion, eg with Benamin. Dr [redacted] replied that the higher level would not matter since treatment could be repeated.

Dr [redacted] asked what the relative instabilities of plutonium DTPA and the mercaptan complex were. Dr [redacted] and Dr [redacted] said they did not know. Dr [redacted] said that the use of Tetracyclines was also possible, Dr [redacted] remarked that Tetracyclines bind to bone.

Capt [redacted] asked Dr [redacted] what, for primary excision, he considered to be a 'significant delay'. Dr [redacted] said about two hours and that it was probably best to combine excision with DTPA.

Dr [redacted] asked what levels of caesium were important. Dr [redacted] said that, as in the case of potassium, it was a question of retention.

Dr [redacted] asked if DTPA was of use in decontaminating skin. Dr [redacted] said that EDTA cream was used in Canada but the UKAEA have used it at the Radiochemical Centre, Amersham and found it not to be of much use.

[redacted]

[redacted]

OFFICIAL [redacted]

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THIRD MEETING OF PANEL N-5
(EFFECTS ON PERSONNEL)
SUB GROUP N
THE TECHNICAL CO-OPERATION PROGRAMME
(TTCP)
16th and 17th APRIL 1969

Part 1: Minutes and Working Group Reports.

Ministry of Defence,
London, S.W.1.

[redacted]

October 1969

THIRD MEETING OF PANEL N-5

SUBGROUP N, TTCP

Held at

MINISTRY OF DEFENCE

WHITEHALL, LONDON

April 16th and 17th, 1969

Part 1: Minutes and Working Group Reports

CONTENTS - PART 1

[redacted]

LIST OF THOSE PRESENT

AUSTRALIA

Surgeon Commander [redacted] RAN	National Leader

CANADA

Mr [redacted]	National Leader
Dr [redacted]	
Surgeon Captain [redacted]	
Colonel [redacted]	
Dr [redacted]	
Dr [redacted]	
Mr [redacted]	Executive Member Subgroup N

UNITED STATES

Captain [redacted] MC USN	National Leader
Dr [redacted]	
Mr [redacted]	
Dr [redacted]	
Lt Colonel [redacted] USAF VC	
Colonel [redacted] USAF MC	
Dr [redacted]	
Dr [redacted]	
Dr [redacted]	
Lt Colonel [redacted] USAF MSC	
Dr [redacted]	
Dr [redacted]	

UNITED KINGDOM

Surgeon Commander [redacted]	National Leader
Dr [redacted]	
Dr [redacted]	
Dr [redacted]	
Wing Commander [redacted]	
Dr [redacted]	
Dr [redacted]	National Leader Subgroup N

UK Observers and Contributors

Squadron Leader [redacted]	
Lt Colonel [redacted]	
Lt Colonel [redacted]	
Major [redacted]	
Mr [redacted]	Panel N-2 (Thermal)
Dr [redacted]	
Mr [redacted]	
Squadron Leader [redacted] (Ret'd)	
Major [redacted]	
Commander [redacted]	
Lt Colonel [redacted]	

Administration by

Mr [redacted]	
Mr [redacted]	

AGREED ACTIONS AND RECOMMENDATIONS

GENERAL

Detailed conclusions and recommendations of the various Working Groups will be provided in the minutes of the meeting. They have been summarised and are provided as Annexes C, D and E to the Agreed Actions and Recommendations of the Panel. The Agreed Actions and Recommendations given below are not provided in any order of priority.

It is recommended:-

a. That the form of NATO STANAG 2083 agreed at b. below be promulgated within each country and especially to the country representatives on relevant NATO Panels, eg NATO Working Panel 225 Panel 7, and the NATO MAS Panel of Experts.

b. That the form of NATO STANAG 2083 now agreed as acceptable to Panel N-5 following detailed examination in executive session, be forwarded together with any necessary explanations to the Canadian Member, Washington Deputies Secretariat for onward transmission to the Air Standardisation Co-ordinating Committee Working Panel 84 as embodying those comments on Air Standard 84/2 requested by that Working Party at their last meeting. The agreed form of the STANAG 2083 is provided at Annex A. This agreement is of course subject to revision in the light of any improved understanding in the future.

(This action will be taken in accordance with the agreed protocol and the papers will be forwarded by the UK Leader Panel N-5 to the Executive Member of Sub Group N for the agreed action to be taken.)

c. That action be taken by the Executive Member of Sub Group N to report, through the Canadian Member, Washington Deputies Secretariat, to the Air Standardisation Co-ordinating Committee Working Party 84 that Panel N-5 has taken note of the Working Party 84 'Permanent Record of NBC Defence Material Requirements'.

d. That the comments on the Army's Standardisation Programme draft QSTAG entitled "Criteria for Protection of Equipment against Nuclear Weapons Effects (U)" given at Annex B be passed to National Leaders, Sub Group N and to the Executive Member, Sub Group N for onward transmission through the appropriate channels.

e. That each participating country evaluate the feasibility of establishing a collaborative, separate, form of data collection from existing channels to obtain information relating to human impact trauma. Particular reference should be made to defining the relationship between important physical parameters and resulting mortality, injury and incapacitation. If feasible such a system should be instituted with all possible haste. And

f. that each country nominate a representative to co-operate in drawing up a common format for data collection and examine the feasibility of carrying out a prospective survey. That the four representatives appoint one co-ordinator to report progress to the National Leaders of Panel N-5 before the next Panel meeting. (NOTE: It is not considered necessary to set up a formal working group for this purpose.)

[redacted]

g. That National Leaders Panel N-5 examine proposals tabled by Canadian National Leader relating to potential hazard from combined radiation-biological agents with a view to formulating an agreed proposal through Sub Group N to Sub Group E.

h. That Sub Group U be asked through Sub Group N to provide Panel N-5 with recommended methods or techniques for the measurement of performance decrement which can be applied to estimate the early effect of ionising radiation on combat effectiveness of personnel.

WORKING GROUPS

i. That the conclusions and recommendations of the three Working Groups be accepted and such action as may be necessary be taken to implement them.

[redacted]

[redacted]

ANNEX A TO AGREED ACTIONS AND RECOMMENDATIONS

NOTE OF EXPLANATION

1. This STANAG was reviewed by Panel N-5 in Executive Session on 16th April, 1969. It was taken as the starting point for review of Air Standard 84.2 which had been itself based on an earlier version of this NATO STANAG.

2. The version provided here, as Annex A to the Recommendations and agreed Actions following this meeting of Panel N-5, has the minimum of minor changes which could have been made. Where possible original wording has been retained so as to avoid upsetting the original authors and perhaps gain easier acceptance of the proposed new version. Eg paragraph 4 of the STANAG is such an obvious statement that it could justifiably be omitted.

3. It cannot be emphasised too strongly that this new version of the STANAG and its Annex A contains only guidance for Commanders. For this reason it is basic. It will be noted, in comparing it with the previous version, that any hint of direction to the Commander who might have to use the Guide has, it is hoped, been removed.

4. Annex B to the STANAG has been revised only with respect to the statements made under the heading 'Incapacitation' in the dose ranges 200-500 rad and 500-1000 rad. This Annex is of course provided only as a basis for medical advice given to a Commander by a Medical Officer.

5. It was also agreed in Executive Session that in the aviation context the following quotation from the Canadian Air Defence Command Handbook for Nuclear Defence Stations, paragraph 2.08 could well be added to the revised version of STANAG 2083 opposite R3 in Column B of Annex A to the STANAG: "Where there is a choice, air crew should be considered unfit for further missions".

[redacted]

APPENDIX I TO ANNEX A TO AGREED ACTIONS AND RECOMMENDATIONS)

STANAG 2083 (REVISED 17TH APRIL 1969 TTCP PANEL N-5

AGREEMENT

1. It is agreed that the NATO Armed Forces will use the information contained herein to enable Commanders to weigh the effects of radiological exposure on armed forces personnel.

GENERAL

2. The final decision on the exposure to which armed forces personnel may be subjected will be made by the responsible Commander. Nothing in this STANAG should be interpreted as limiting the Commander's authority in this respect.

3. The exposures shown cover those which might be expected to have an effect on the military effectiveness of armed forces personnel in war.

4. In nuclear warfare, military operations may require that peacetime regulations on limits of radiation exposure and requirements for radiation protection be exceeded.

5. The danger involved in radiological exposure must be evaluated in accordance with the military situation and the state of emergency.

RADIOLOGICAL HAZARD

6. All nuclear radiation, even in very small exposures, has some harmful effect on the body and should be avoided whenever possible to do so without interfering with military operations.

7. All nuclear radiation exposures referred to are external, whole body, from initial or residual penetrating radiation or both.

8. Some of the factors influencing injury caused by penetrating nuclear radiation are:

a. the total exposure accumulated from previous radiation exposure;

b. the periods over which the exposure are received;

c. the periods of recuperation between radiological exposures;

d. the presence or absence of any additional injuries or incapacitation;

e. the physical condition, sex and age of the individual at the time of the radiological exposure.

9. Recovery from radiation injury has not been completely assessed in accordance with the best available biological data and for the purpose of operational evaluation of radiation exposures is not considered to have any military significance.

ASSESSMENT OF THE HAZARD

10. Commander's Guide on Radiation Exposure State. Annex A provides a broad

guide for use by commanders, as to the effects of radiation in terms of combat effectiveness. It is based upon the reaction of groups to radiation and should normally be applied to units or sub-units. Exceptionally, in the absence of any better information, it may be applied to individuals - in which case it will suggest probability of combat effectiveness.

11. Probable consequences of exposure are contained in Annex A, Column (b). The information should be regarded as a guide only since it assumes that:

a. All exposures to radiation are directly additive and cumulative in their effect;

b. the factors in paragraphs 8b - e are ignored;

c. estimates of the actual exposure received are likely to be accurate only to within plus or mimus 50%;

d. recovery from radiation injury does not occur.

12. Radiation Exposure State

a. The Radiation Exposure State (RES) is an estimate, indicated by an exposure categorization symbol, which may be applied to a unit, sub-unit (or exceptionally, to an individual). It is based on total cumulative exposure received.

b. The RES provides a convenient method of enabling information regarding radiation exposure to be exchanged. Since it is directly related to effects of tactical interest, it can be used for estimating the effectiveness of groups or individuals and can be employed when planning future exposure.

13. Expected Response to Acute Penetrating Radiation in Man Annex B is a table representing NATO medical opinion concerning the more detailed effects of radiation on groups of individuals. It provides further background information for use by medical advisers to commanders in assessing the overall effects of radiation on personnel.

14. Radiation Exposure Assessment. It is not the intention of this STANAG to include a system of radiation exposure assessment. Implementation, however, presupposes the establishment of a suitable system.

IMPLEMENTATION OF THIS AGREEMENT

15. The STANAG will be considered to have been implemented when the necessary orders/instructions putting the procedures and format detailed in this Agreement into effect have been issued to the forces concerned.

ANNEX 'A' to STANAG 2083 (revised 17th April 1969 TTCP Panel N5)

COMMANDERS' GUIDE ON RADIATION EXPOSURE STATE

RES Category (a)	Probable consequences (b)	Total comulative exposure (c)
R 1.	None. Fully combat effective.	Less than 100 rad
R 2.	Slight decrease in combat effectivenss possible at the upper limit.	100-200rad
R 3.	Probably not able to perform complex tasks reliably. Sustained effort hampered for period of 6 to 20 hours.	200-500rad
R 4.	Severe incapacitation as exposure increases. After initial illness temporary recovery might be expected in the lower exposure range.	over 500rad

NOTES 1. Combat ineffectiveness is taken to be the onset of severe nausea and vomiting.

2. For the purpose of this Guide the exposures in column (c) all defined to be the same as the exposures in Roentgens (R).

ANNEX 'B' STANAG 2083 (revised 17th April 1969 TTCP Panel N5)

EXPECTED RESPONSE TO ACUTE PENETRATING RADIATION IN MAN

ESTIMATED SURFACE EXPOSURE RANGE (RAD)	INITIAL SYMPTOMS	ONSET OF SYMPTOMS	INCAPACITATION	HOSPITALIZATION	DURATION OF HOSPITALIZATION	FINAL DISPOSITION
0-100	None	None (Blood changes detectable in upper part of range)	Home	Home	-	Duty
100-200	None to transient mild headache nausea and vomiting	Approx. 3-6 hrs after exposure	None to slight decrease in ability to conduct normal duties.	Eventual hospitalization required for less than 5% in upper part of range.	20 to 30 days in upper part of range.	Duty. No deaths anticipated
200-500	Headaches, nausea and vomiting; fatigue	Within 3 hrs after exposure	Probably not able to perform complex tasks reliably. Sustained effort hampered for period of 6 to 20 hrs.	Eventual Hospitalization required for 90% of exposed personnel in this range Hospitalization follows latest period of 10 to 30 days duration.	30 to 90 days	Some deaths anticipated; probably less than 5% at lower part of range, increasing toward upper end. Return to duty questionable in upper range.
500-1000	Severe Nausea and vomiting. Fever early in upper part of dose range.	Within 1 hour after exposure.	Severe incapacitation as exposure increases. After initial illness temporary recovery might be expect in the lower exposure range.	Subject to triage hospitalization required for 100% of exposed personnel. Latent period 7-10 days in lower range to none in upper range.	90 to 120 days for those surviving.	Approx 50% deaths at lower part of range, increasing towards upper end; all deaths occuring within 48 days.

[redacted]

ANNEX B TO AGREED ACTIONS AND RECOMMENDATIONS

It was agreed that TTCP Panel N-5 could see no justification whatsoever for regarding the 3,000 rad figure (or the other 1,000 rad and 5,000 rad figures commonly associated with it) proposed for use in the QSTAG as having any but the crudest biomedical substantiation and there is no support for using this figure in any precise manner in any biomedical context.

2. TTCP Panel N-5 could see no reason why these figures should not continue to be used for the purpose for which they were chosen so long as the above statement is fully recognised. But, it is possible that recent and future work on the short term incapacitation effect of high dose might invalidate the figure chosen for radiation exposure, and recent work on chemoprophylactic agents might provide a means of combating the performance decrement phase at these high doses.

[redacted]

ANNEX C AGREED ACTIONS AND RECOMMENDATIONS

WORKING GROUP ON RADIAC REQUIREMENTS
MEETING 14th/15th APRIL, 1969

Conclusions

We conclude that the commanders guides could be applied with the aid of Radiac instruments in service or about to come into service (i.e. in advanced design stage) but we consider there is some uncertainty in the validity of the guides. This uncertainty is due to lack of information on their derivation and the probability that they are based on the table of effects compiled some ten years ago which should be reviewed in the light of information obtained since. We are concerned over the accuracy implied by the guides and its implication for instrument design. Lists of instruments have been compiled and are available from working group members.

2. The unit of dose recommended for incorporation in instruments i.e. tissue or water, midline or surface, measured on the body or in air is considered to be not important until such time as the table of effects can be described more accurately. This statement is especially true in recognition of the random orientation of personnel expected when large numbers of exposures occur.

3. At the present time dose rate meters give a measure of dose between the exposure and the midline dose. Dosimeters for γ and n radiations are in advanced states of design but the prime difficulty is assigning a dose equivalent to the neutrons.

It is our opinion that an indirect reading dosimeter should be a personal issue to all personnel. It can be of value in the tactical sense (if a convenient reader is provided) and can certainly provide a measure of individual radiation exposure when this is required (to determine radiation states for example).

4. We cannot at this time specify the characteristics for ideal dosimeters nor the preferred body locations: these subjects remain under study.

[redacted]

ANNEX D TO AGREED ACTIONS AND RECOMMENDATIONS

CHEMOPROPHYLAXIS WORKING GROUP

January 27th, 1969

It is recommended that:-

1. The human tolerance trials with agent WR38 be continued and that the agents WR2529 and WR2721 be added to the trial programme as soon as possible.

2. Work continue with compound WR2823 and some of its analogues to further explore their use in treatment of hemorrhagic and other clinical types of shock.

3. More emphasis be placed on structural modifications which will explore the lead to make the agents more effective by the oral route.

4. A continuing effort be made to find new covering functions which are easily split off in vivo from the sulfur atom and which will improve the distribution of the agent to the critical tissues.

5. Research continue to uncover protective agents which are more specific for the protection of the gut and central nervous system.

6. Further exploration of combination of protective agents be made to obtain the maximum protection factor and to find the biological system which fails.

7. Emphasis continue to obtain data on the distribution in rodents and other animals of the newer agents with different covering functions and that the studies include the identification of the administered agents and their metabolities in the haemopoietic, gastrointestinal tissues and the central nervous system.

8. Research on the mechanisms of protective action be continued and that the investigations include model systems for aqueous radiation chemistry studies as well as biological systems.

9. The thiol analogue of the new agents be tested in mammalian cellular systems and that oxygen concentration in the spleen and bone marrow of whole animals be determined after the administration of the new agents to reveal if their mode of action is pharmacological.

10. Although the present evidence shows that steric and optical isomeric effects are not important, a small effort should be made to firmly substantiate this conclusion.

11. The general pharmacology studies be continued to uncover side effects and provide data useful for elucidating mechanism of actions.

[redacted]

ANNEX E TO AGREED ACTIONS AND RECOMMENDATIONS

THERAPY REGIMES WORKING GROUP
MEETING 14TH/15TH APRIL, 1969

1. Thermal Injury

It is recommended that:-

1. Triage

Triage principles must be applied to all patients with thermal injuries. The responsibility for triage should reside with the most experienced available person, and the principles are re-applied for each stage of therapy for each patient.

2. Burn Wound Care

Burn wound care, resuscitation and rehabilitation should be in accordance with the principles described more fully in the text of the minutes of the Meeting of Working Panel N-5 held in London on April 16th/17th, 1969.

3. a. Immediate Wound Coverage

A light, easily packaged, and sterile material should be available to afford protection to the burn wound at the time of initial cleansing and during transportation. Logistic problems, porosity, heat transmission properties, and sterilising methods should be investigated.

b. Resuscitation Therapy

Further information should be available concerning the efficacy of different types of fluid used during the resuscitative period. Controversy continues to rage about the problem of saline versus colloid replacement therapy. A plasma or colloid solution should be available in a dry form (suitable for reconstitution and use) at the advanced casualty centres.

c. Pulmonary Damage

Improved substances and techniques should be available for therapy for pulmonary damage. There exists a definite lack of understanding concerning the pathological biochemical and functional changes that occur in the burned lung, with and without direct injury. More information is definitely needed to improve survival.

d. Eschar Treatment and Removal

A rapid method for the removal of burn eschar shortly after burning should be developed, and at the same time a readily available skin substitute should be available. This "skin substitute" must be light-weight, flexible, water-protective and bacteriostatic. It must also be fairly non-reactive to the underlying tissues. In addition, prior to and following the possible removal of the burn eschar, improved chemotherapeutic agents with a wider range of effectiveness should be searched for that can be easily stored in dried bulk form and reconstituted at the advanced casualty centre. Improved grafting methods should continue to be investigated, although use of these is most applicable at definitive care centres.

[redacted]

e. Cellular Response to Injury

Further basic research is needed in the fields of the sub-cellular and cellular response to injury, the response of the immune system to injury and the effect of "catabolic-protective" agents upon the injured patients. These wide fields of endeavour deserve intensive investigation.

f. Prophylactic Vaccination

Enlarged clinical trials should be conducted to determine the efficiency of vaccinating "high risk" persons against suitable pathogenic bacteria, i.e. pseudomonas aeruginosa. Improved antigens and techniques for use are also needed.

g. Anti-Inflammatory and Analgesic Agents

No effective local or systemic anti-inflammatory agents are available and, in selected clinical situations, they could be very useful. Narcotics are generally unsatisfactory when used to treat "burn pain", and they also have undesirable side effects. Active research for new compounds with these properties should be pursued.

h. Performance Decrement - Human

Clinical data should be obtained on the effects of both extent and type of burns injury upon performance under different stress situations.

2. Radiation Injury

It is recommended that:-

1. Dose Rate Studies

Information is required as to whether very high dose rates would produce a more severe clinical episode than would low dose rates.

2. Influence of Diet

In spite of many studies on the intestinal flora and their relation to many manifestations of acute radiation injury, information is still needed as to whether to provide human beings with high or low residue diets or with changes in balance between fat, carbohydrate or protein.

3. Study should be made of the most appropriate fluid therapy for radiation casualties. Possibly the saline solutions recommended for thermal casualities could usefully be employed.

4. Immune Systems

Further implications of work with immunosuppressive agents should he analysed with a view towards relating these methods to allografts of bone marrow. Studies of lymphocytes and stem cells to develop transplantable cultures with specific immune capabilities should be considered.

5. Typhoid-paratyphoid A and B vaccine should be investigated as a stimulant for haematopoietic recovery in man. Other agents producing a similar effect should be studied.

[redacted]

3. Blast Injury

It is recommended that the suggested therapeutic approach to blast injury, provided in detail in the recommendations of Working Groups as part of the minutes of the Meeting of Panel N-5, be adopted by the four countries.

2. It is further recommended that studies are required to provide further information on the efficacy of pressurization, on the use of anticoagulants and on the most beneficial combination of therapeutic procedures, in the treatment of blast injury.

AGENDA ITEM 1

DISCUSSION WITH UK SERVICE STAFF REPRESENTATIVES ON "USER ASPECTS OF COMMANDERS GUIDES"

COMMANDERS GUIDE - NAVAL REQUIREMENT (Presented by Commander [redacted] RN)

Scenario

1. In general, ships will be at nuclear separation distances. This means that for point target nuclear attacks the initial radiation received by men in protected positions in ships in compnay will be low ie less than 75 rads.

2. Contamination of ships by fall-out will be much reduced by wash down systems.

3. We therefore now think that situations involving high total radiation doses to ships personnel are less likely than were once thought although one cannot be too dogmatic about this.

Need for Information on the Effects of Radiation

4. The Command. Needs a broad picture of the radiation state of the ships company on which to base tactical decisions where a choice exists. For example it may be useful to know that for a given background dose rate and initial dose level, a given percentage of the crew would be sick in one, two or three days time.

5. The NBC Protection Officer. Needs a guide to enable him to advise on the rotation of men in areas of high background for instance in contaminated machinery spaces.

6. In both these cases precise information on effects is of doubtful value since:

1) Dosimetry is inaccurate
2) The curve of effects v dose rises rapidly above 200 rads.

Information Available

7. The Naval NBCD would contain three tables showing zones of effects - all slightly different from each other and different from the table of zones contained in the 2nd Draft of Edition No 2 of STANAG 2083.

Alternative presentation

8. The Table contained in NAVMED P1330 June 1951 - Handbook of Atomic Weapons for Medical Officers reproduced by Dr Alpen in his paper presented to the 12th Tripartite Conference on Toxicoligical Warfare in September 1957 was at that time considered by Dr Alpen to be unsatisfactory since the biological basis for the figures was then considered by him to be of doubtful accuracy.

9. If Medical evidence is now sufficiently extensive to justify a return to this type of presentation it would be an improvement on the zones of effects tables since it incorporates at a glance the time factor.

General

10. If this is not the case, then the comparatively crude zones of effects tables - perhaps brought up to date and agreed are adequate to meet naval needs.

COMMANDERS GUIDE - ARMY REQUIREMENT (Presented by Lieutenant Colonel [redacted])

1. The UK Army interest in human response to weapon effects arises from:-

a. Revision of casualty tables

b. Assessing levels for the hardening of equipment

c. Guides for commanders in the field.

2. Medical experts in NATO have studied the radiation problem and have produced STANAG 2083. This contains two appendices:-

Appendix B - gives the medical man's advice to soldiers.

Appendix A - gives the soldier's interpretation.

3. The onset of incapacitation is the thing which really matters eg is this at about 150 or 200 rem. The UK Army is also interested in a halfway stage as a control level eg at 75 or 100 rem. The UK is not interested in higher levels of radiation in a Commander's Guide but would not disagree with their inclusion if NATO wanted this.

4. The UK has made minor comments on STANAG 2083 but are waiting for the Panel to consider the actual figures quoted before ratifying the document.

5. The correct and consistent use of units is necessary.

COMMANDERS GUIDE - RAF REQUIREMENT (Presented by Squadron [redacted])

Introduction

1. The development of a Guide to the effects of radiation must take account of situations in which the operational task may assume overriding importance, and others in which the threat of radiation casualties may outweigh the importance of a particular operation. The duration of primary operational roles of the RAF will vary considerably, from hours to months, therefore, the guide should cover a period of at least up to 30 days, preferably 3 months.

Stanag 2083

2. This 'STANAG' was accepted, being the best information available. The Guide Annex A will prove to be of great value for use by Formation Commanders in assessing and reporting overall situations and should generally be used at that level of command. Nevertheless Unit Commanders require greater detail than is shown in 'Guide', Annex B.

[redacted]

[redacted]

Proposals For Discussion

3. Appendix A (attached). Casualty Risk Table dated 1958. This table was accepted, with reservations, for training purposes. It was used extensively during large scale exercises in which Stations/Units operated in a radiation environment. The Tables proved to be feasible, and realistic exercise settings were possible within the obvious limitations. The major criticism being lack of detail on the time/scale of effects.

4. Appendix B (attached). Casualty Risk Table for Use by Single Ship, Station, and Army Unit Commanders. This table has been produced as a possible replacement for Appendix A. The stages of effects are only a layman's assessment and should be treated as a suggested layout rather than factual content. This type of table would be acceptable for use at unit level and be considered a step forward in meeting the requirement.

5. Appendix C. This layout - if it is possible to fully complete - would be the ideal for the future. One page would be required for each dose band, and should reflect reference dose bands which can be associated with biological effects causing combat effectiveness in individuals or groups, given in terms of:

a. time to onset;

b. time of exposure;

c. duration of effect.

Conclusion

6. Station and Unit Commanders require Guides presenting information in greater detail than existing ones, for reference when preparing plans for:

a. operational tasks;

b. unit resuscitation.

7. STANAG 2083 Annex A 'Guide' to be used at Formation level.

8. Guide Appendix B - if feasible - should be considered for the immediate future, and Guide Appendix C should be considered an ultimate aim.

[redacted]

CASUALTY RISK TABLE

APPENDIX 'A'

Estimated Medical Effects of Radiation Doses Expressed as Probability of Sickness or Death

Measured	Early Effects for Periods of Time Over which Total Dose is Received										
			3 Days		1 Week		1 Month		3 mo. or more		
	Sickness	Death	Sickness	Death	Sickness	Death	Sickness	Death	Sickness	Death	Significant Late Effect
0 to 75	0%	0%	0	0	0	0	0	0	0	0	None
100	2%	0%	0	0	0	0	0	0	0	0	None
125	15%	0%	2%	0%	0	0	0	0	0	0	None
150	25%	0%	10%	0%	2%	0%	0	0	0	0	None
200	50%	0%	25%	0%	15%	0%	2%	0%	0%	0%	Some
300	100%	20%	60%	5%	40%	0%	15%	0%	0%	0%	Some
450	100%	50%	100%	25%	90%	15%	50%	0%	5%	0%	Some
650	100%	95%	100%	90%	100%	40%	80%	10%	10%	0%	Some

This table applies to healthy, young adults under usual working conditions. The probability of fatalities will be decreased with adequate medical treatment. The casualty estimates are based on an interpretation of the best current available evidence and may be changed as more information is accumulated.

Date of Preparation 16th April 1958

CASUALTY RISK TABLE

APPENDIX 'B'

FOR USE BY SINGLE RN SHIP, RAF STATION AND ARMY UNIT COMMANDERS

EARLY EFFECTS FOR PERIODS OF TIME OVER WHICH TOTAL DOES IS RECEIVED															
	1 HOUR					6 HOURS					12 HOURS				
Measured Dose	Vomiting	Significant Impairment of:			Death	Vomiting	Significant Impairment of:			Death	Vomiting	Significant Impairment of:			Death
		Speech	Vision	Physical Co-ordination			Speech	Vision	Physical Co-ordination			Speech	Vision	Physical Co-ordination	
0-75															
100															
125															
150															
200															
300															
450															
650															

Definition of Significant Impairment:

Speech: Inability to pass a message verbally by telephone radio, clearly.

Vision: Inability to read instruments, dials, documents accurately.

Physical Co-ordination: Inability to write, to walk, to operate manual controls on equipments/Instruments properly.

CONTINUATION OF CASUALTY RISK TABLE

	1 DAY					2 DAYS					3 DAYS				
0-75															
100															
125															
150															
200															
300															
450															
650															

	1 WEEK					2 WEEKS					3 WEEKS				
0-75															
100															
125															
150															
200															
300															
450															
650															

CONTINUATION OF CASUALTY RISK TABLE

	1 MONTH					2 MONTHS					SIGNIFICANT LATE EFFECTS				
0-75															
100															
125															
150															
200															
300															
450															
650															

DOSE RANGE TO

EFFECTS/TIME SCALE

APPENDIX 'C'

		1 hr	2 hrs	3 hrs	6 hrs	12 hrs	1 day	2 days	3 days	1 week	2 weeks	1 month	3 months plus
	INITIAL RADIATION												
	1 hr												
	2 hrs												
	3 hrs												
ABSORB-TION TIME	6 hrs												
	12 hrs												
	1 day												
	2 days												
	3 days												
	1 week												
	2 weeks												
	1 month												
	3 months plus												

DISCUSSION

The Chairman summarised the Service positions as follows:-

a. RN - in the case of radiation doses to personnel they assumed that nuclear separation distances would be effective but otherwise they relied on 'zones of effects' tables.

b. Army - were interested in the onset of incapacitation and in the correct use of units.

c. RAF - had a requirement to state the meaning of incapacitation, being interested in the relationship between dose, time of dose absorption and time to incapacity.

Mr Longair inquired whether he could ask Commander Shand if ships would be individual targets, in a scenario agreed in 1962 it was envisaged that a task force would be attacked by a megaton weapon. Commander Shand said the scenario he had quoted was current in-house thinking but may not be current NATO thinking. Dr Alpen said that the US Navy agreed with the RN view for the case of ships on the high seas, since, due to the high precision of delivery systems, yields were not important. The US Navy were currently considering eight scenarios for differing situations. Mr Longair said he would seek further advice.

AGENDA ITEM 2

DISCUSSION ON A DRAFT QSTAG DATED 1ST DECEMBER 1968 ON EQUIPMENT HARDENING entitled "Criteria for Protection of Equipment against Nuclear Weapon Effects".

1. The Chairman said that the adoption of 3,000 rad for producing 50% incapacitation of personnel within one hour could only be regarded as a crude figure from the biological point of view, but it was a reasonable figure to use in this context. It was important that it should not be used as a precise figure for biomedical purposes and should not be used out of context. Captain [redacted] agreed with the statement made by the Chairman. Mr [redacted] said the position had not changed since the last meeting. Dr [redacted] pointed out that adoption of the 3,000 rad dose as being equivalent to 50% incapacitation within one hour was conservative for equipment.

2. Mr [redacted] said the ground had been worked over several times and he would now like to see the QSTAG put to bed. The Chairman considered that the general paraphrase of their views produced as a result of the discussion at the last meeting (and passed to Mr [redacted]) was still acceptable. Captain [redacted], Mr [redacted] and Surgeon Commander [redacted] agreed and a form of words was accepted by all National Leaders which would be forwarded to the Subgroup for onward transmission.

AGENDA ITEM 4. RELATIONSHIP WITH SERVICE STANDARDISATION ORGANISATIONS (ASCC WORKING PARTY 84, AIR STANDARD 84/2; NATO STANAG 2083, 2ND EDITION, 2ND DRAFT; NATO MAS (ARMY) MED/NBC (68), 1ST MEETING, 10TH JUNE 1968, ANNEXES B AND C

Mr [redacted], in presenting the Canadian point of view, said they probably had more direct contact with the Services due to their smallness. Co-ordination was reasonably good except for the case of the NATO MED/NBC Group on which they had no representation. The greatest difficulty arose in the frequent changes of personnel which occurred (eg the ASCC Working Party 84 representative had changed three times in the past year), further trouble arose from the timing of meetings of different organisations which were difficult to synchronise. The distribution of minutes was not well organised and could be improved.

Commander [redacted] said that in Australia the Air Force used Working Party 84.

Captain [redacted] said his was a state of confusion. They had circulation problems, frequently documents did not reach them, if they did arrive they were often late.

The Chairman thanked the National Leaders for their statements and commented that this was not a satisfactory state of affairs. It was desirable to ensure that an action continues to be placed on the agenda of every meeting of the Panel to consider relationships with Service Standardisation Organisations.

The Chairman drew attention to the recommendations from the UK for TTCP to examine STANAG 2083; also to the request from the Air Standardisation Co-ordinating Committee, Working Party 84 to forward recommendations to them on Air Standard 84/2 and STANAG 2083 before the next meeting. Dr [redacted] said that the US Navy did not accept STANAG 2083, they considered that it was overly complicated and that the RES categories were not acceptable. Commanders Guides were intended for guidance in making decisions, but they were unrealistic since the time in which the dose was received was not stated. They were also limited in respect of the range of dose covered, there was a need for information in the range of 200 rad to tens of thousands of rads. The Chairman pointed out that the aim of the meeting was to produce guidance to all three Services in all four countries. Dr [redacted] said that the broad band curves were the best available and that NWP 28 A was still the best guide. Nothing could be done to produce information of the type suggested by the RAF in their presentation and in any case Commanders would be unable to use this information even if it were made available. Furthermore the RES system implies treatment on the basis of dose rather than symptoms. Squadron Leader [redacted] said that RES is merely a shorthand dose reporting system. Dr [redacted] said that better data would be available from Nuclear Weapon Information Centres and that he thought the US Army had abandoned RES five years ago. In his opinion the most that could be said is that the likelihood is good if the dose received in under one month is kept below 200 rad and the dose received in over one month kept below 500 rad.

Lieutenant Colonel [redacted] asked Dr [redacted] if, in his view, dosimeters were necessary. Dr [redacted] replied that they were and, in reply to a query from Lt Col [redacted] whether it was worth having a dosimeter from the morale point of view, said that although a few in the US felt that no dosimetry was required it was his opinion that dosimetry was still useful for medical guidance.

Dr [redacted] inquired if, from the tactical viewpoint, dosimetry could be improved. Dr [redacted] considered that there were too many other factors involved and there would be neither the time nor the manpower during a battle to handle this information, in any case information for this purpose would be available from area survey. Dr Jacobus felt information from that source would be patchy while Dr [redacted] suggested that symptomatology would provide information.

In reply to a question from Commander Shand as to whether there was tri-service agreement in the US, Captain Stark said there was no evidence of tri-service agreement and he felt that ratification of STANAG 2083 had not been carried out by bodies qualified to do so. He further felt that paragraph 11 of the STANAG in fact invalidated the whole of it. Mr [redacted] said it was no use carrying on the discussion without trying to give advice.

In response to an invitation from the Chairman, Lt Col [redacted] outlined the history of the production of Annex B to STANAG 2083. He said that the NATO MAS Panel of Experts served three masters:- the NATO Armaments Committee; the NATO MAS Medical Working Party; and the Working Party which prepared STANAG 2083. The information in Annex B to the STANAG was largely derived from CDOG Study USACDCNG 62-8. There was a large measure of agreement on this Annex within NATO and the notes on the back spelled out the restrictions in its use. Annex A to the STANAG was the responsibility of another Working Party, there was disagreement in this on whether 150 rad or 200 rad should be used, both values were to be found in the CDOG Study. In response to a question from the Chairman, Lt Col [redacted] replied that the information on blast and thermal injuries contained in the MAS MED/NBC Report was largely derived from the CDOG Study.

Dr [redacted] commented that the usual practise in medical institutions was to tell as much as possible, there was some implication in the discussions of a limitation in the ability of people to absorb information.

Mr [redacted] asked if the US Army Combat Development Command still agreed with the RES Category concept. The Chairman quoted from a letter from CDC to Lt Col [redacted] which stated that USACDCNG 62-8 was still current US Army doctrine; the Study was now undergoing a revision which was expected to be complete in the second quarter of 1970 and that significant changes in casualty criteria would be made. The Chairman went on to say that they appeared to have reached an impasse on the question of STANAG 2083 in view of the opposition of the US Navy. In the case of ASCC Working Party 84 he was hopeful of producing a form of words as guidance. Dr [redacted] said he was quite happy to stand aside and let the majority decide what they wanted. He was quite certain however that, despite US Army acceptance of STANAG 2083, the US Army Surgeon-General did not accept Annex A. A decision reached on the basis of reading a dosimeter was not valid.

Dr [redacted] said there were two questions involved, firstly 'Command and Control', secondly medical effects. The production of Commanders Guides was not a function of the Panel which should however provide a basis for them. [redacted] said that TTCP was not set up for this sort of thing and suggested that they should deal with it in executive session. Dr [redacted] said that the Panel should examine the STANAG and comment on it where it gave poor guidance, he agreed that a small group should consider it. Captain [redacted] said there was no clear indication as to what STANAG 2083 was meant to be, he would like to see a definition of its exact purpose. It should be solely for the purpose of providing guidance to Commanders. He referred to the statement in paragraph 13 - "It is intended to provide further background for use by Commanders in assessing the overall effects of radiation on personnel under their command." He agreed with Dr Alpen that it was impossible to write a document for all Services for all situations. He considered that paragraph 13 should be paragraph 1.

Dr [redacted] considered the Panel's task to be one of providing data, eg on performance decrement; they should get on with the technical task of refining data and then passing it on. Dr [redacted] questioned what kind of performance decrement they were interested in, they had to segregate this thinking. The information they produced might not be used for 20 years, it was not conceptually difficult but at least it would enable people to talk.

Dr [redacted] said that essentially there was no interservice disagreement in the US. The disagreement were firstly on the use of a category with an upper dose limit of 75 rad, this was conceptually bad since nothing happened at this dose; secondly on the interpretation of use, the US regarded Commander's Guides as 'rules of thumb', NATO regarded them as a specification which Commanders would use.

AGENDA ITEM 13. RELATIONSHIP WITH OTHER SUBGROUPS ETC

1. Canada tabled two papers on relationships between Panel N-5 and Subgroup U, and between Panel N-5 and Subgroup E.

In view of the fact that a Subgroup U meeting was due to take place within a few days in London action on Canada's paper was agreed then and there to the effect that: "Subgroup U be asked through Subgroup N to provide Panel N-5 with recommended methods or techniques of measurement of performance decrement which can be applied to estimate the early effects of ionising radiation on the combat effectiveness of personnel".

It was agreed that the second Canadian Note on Relation with Subgroup E'be examined by N-5 National Leaders with a view to formulating an agreed proposal through Subgroup N to Subgroup E.

2. It was noted that an N-2/N-5 Working Party had been set up in the UK to examine the problem of burns under clothing and that a detailed review of the data on the production of burns on bare skin and under clothing is well under way.

RELATION WITH SUB GROUP U

At the 8th meeting August 10th-12th, 1966, Canada of Sub Group N, the Canadian proposal for the study of response of humans to ionizing radiation was discussed and the following action drafted.:

"ITEM 8

The Canadian proposal for the study of the response of humans to ionizing radiation is unanimously and strongly supported. Other member countries will assist to the fullest on the basis of their experience and data."

At the eleventh meeting of Sub Group N, 6th-8th August, 1968, the response of humans to ionizing radiation was again discussed. In the meantime, a new Sub Group U on Human Factors was finally established and their terms of reference can be taken to include the effects of ionizing radiation on personnel. Sub Group N has requested panel N-5 for a statement of what is required from Sub Group U on the question of decrement of performance.

It is suggested that Sub Group N request Sub Group U to have the topic "The Early Effects of Exposure to Ionization and Operational Effectiveness of Personnel" placed on their agenda for the meeting to be held on May 5th-9th 1969, at Army Personnel Research Establishment, Farnborough, Hants, England.

The following statement can be used as the general aim of the project:-

It is important to obtain information applicable to military problems on the early response of humans to ionizing radiation. Emphasis will be on those effects related to critical, physical and mental requirements of specific combat tasks. This information will be used to relate exposure dose to performance decrements and in capacitation in commanders guides for estimate of combat effectiveness or casualty production.

Now panel N-5 should be provided with further information by Sub Group U on the specific combat task and time elements involved in order that they sponsor the design of tests to measure the decrement of performance in the special combat tasks.

It should also be remembered that since the evaluation will be done in therapeutic wards of the hospitals, the type of tests designed will be limited and we should carefully choose specific combat tasks that can be evaluated.

Relation with Subgroup E

Investigations have shown that the combined effects of radiation and biological organisms warrants further studies. When radiation is delivered at a slow dose-rate of approximately 1 to 2 rads/hr to accumulate total doses of 500 to 2000 rads to mice, an increase in susceptibility by the mice to some organisms by orders of magnitude has been observed.

When employing pathogenic organisms and dosing the animals with a small number of organisms (i.e. 10 to 100) in aerosols, the facilities and the expertness for carrying out the investigation are not usually available in laboratories involved in radiobiological studies. Canada did have available these combined facilities and expertness, but a recent reorganization has made these unique facilities no longer available at the present time.

The hazard from the combined radiation-biological agent has not been completely determined and appears to be the most important of the combined effects studied. The data for this combined effect is required not only to outline the military hazard but for inclusion in emergency measures guides.

The following parameters require further study to determine the total dose and dose-rate which is likely to increase the susceptibility of man to biological agents:

1. dose-rate, 1 to 10 r/hr. Total doses 300 to 1000 rads;

2. different animal species;

3. bacteriological agents, live and dead vaccines, non-pathogenic organisms, organisms causing contagious diseases, biological agents considered for biological warfare.

Considering the parameters to be studied, Panel N-5 suggests it would be more feasible for radiation facilities to be placed in laboratories already organized to carry out biological research with pathogenic organisms than those already devoted to radiobiological studies.

Panel N-5 request that Subgroup N forward to Subgroup E for further action the following proposal:

Panel N-5 would assist with radiation facilities and guidance for radiation parameters to be studied and Subgroup E through Panel E_2 would be responsible for exposure and choice of biological agents and animal species.

That a working group composed of Panel N-5 and Penel E_2 members be formed to co-ordinate the project and to investigate the most efficient way of carrying out the investigations.

WORKING GROUP REPORTS

CHEMOPROPHYLAXIS WORKING GROUP
27TH JANUARY 1969

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION 1.

The evidence from the human tolerance trials with protective agent WR638 (2-aminoethylthiophosphoric acid) indicates that man can tolerate levels of this compound on a mg/kg basis that have been shown to be protective for several species of animals.

RECOMMENDATION 1.

It is recommended that the human tolerance trials with agent WR638 be continued and that the agents WR2529 and WR2721 be added to the trial program as soon as possible.

CONCLUSION 2.

It has been noted that the following recommendation of the 1967 minutes has not been implemented: "The better agents which protect the 'CNS' from radiation effect should be evaluated for possible inclusion in weapon systems; if an agent is considered for use as a nuclear weapons system component then a suitable analysis (wargames) should be performed".

RECOMMENDATION 2.

It is recommended that CNS protective agent data be considered in systems analysis (wargames) along with nuclear weapons data.

CONCLUSION 3.

The compound WR2823 $NH_2(CH_2)_5NHCH_2CH_2S - \overset{O}{\overset{\|}{P}}(OH)(OH)$ has been found to be a specific α adrenergic blocking agent for the vascular receptor sites and a useful agent for the treatment of hemorrhagic shock in dogs and monkeys.

RECOMMENDATION 3.

It is recommended that work continue with compound WR2823 and some of its analogues to further explore their use in treatment of hemorrhagic and other clinical types of shock.

CONCLUSION 4.

The lipid-soluble derivatives of the protective agents have been structurally modified so that they show some effectiveness by the oral route.

RECOMMENDATION 4.

It is recommended that more emphasis be placed on structural modifications which will explore the lead to make the agents more effective by the oral route.

[redacted]

CONCLUSION 5.

Of the new covering functions for the thiol group investigated the following structures showed promise:

(a) RSSSSR

(b) $R - S - C(=NH)(NH_2)$

(c) $R - S - \overset{O}{\overset{\|}{C}} - CF_3$

(d) $R - SS(CH_2)_3CH_2SO_2Na$

(e) $R - S - \overset{O}{\overset{\|}{C}} - SCH_2CH_2COOH$

RECOMMENDATION 5.

It is recommended that a continuing effort be made to find new covering functions which are easily split off in vivo from the sulfur atom and which will improve the distribution of the agent to the critical tissues.

CONCLUSION 6.

There is a growing awareness of the specificity of protective agents to protect different biological systems and if greater protective levels in the whole animal are to be obtained the protection to the gut and CNS tissues must be improved.

RECOMMENDATION 6.

It is recommended that research continue to uncover protective agents which are more specific for the protection of the gut and central nervous system.

CONCLUSION 7.

Dose reduction factors of 2 to 3 have been found when combinations of protective agents have been administered to mice.

RECOMMENDATION 7.

It is recommended that further exploration of combination of protective agents be made to obtain the maximum protection factor and to find the biological system which fails.

CONCLUSION 8.

Although some efforts have been made to determine the distribution of some of the newer agents in mice, the data are not sufficient to determine the concentration of the administrated agent and its metabolite in all the critical tissue systems.

RECOMMENDATION 8.

It is recommended that emphasis continue to obtain data on the distribution in rodents and other animals of the newer agents with different covering functions and that the studies include the identification of the administered agents and their metabolities in the haemopoietic, gastrointestinal tissues and the central nervous system.

[redacted]

CONCLUSION 9.

There are not sufficient data to derive mechanisms of action for protective agents which are in accordance with all the experimental facts.

RECOMMENDATION 9.

It is recommended that research on the mechanisms of protective action be continued and that the investigations include model systems for aqueous radiation chemistry studies as well as biological systems.

CONCLUSION 10.

The mode of action of the lipid soluble new agents and of others with intermediate water solubility is unknown.

RECOMMENDATION 10

It is recommended that the thiol analogue of the new agents be tested in mammalian cellular systems and that oxygen concentration in the spleen and bone marrow of whole animals be determined after the administration of the new agents to reveal if their mode of action is pharmacological.

CONCLUSION 11.

The few investigations on the effects of steric and optical isomers on protective potency have shown that these factors do not influence protective potency to any great extent.

RECOMMENDATION 11.

It is recommended that, although the present evidence shows that steric and optical isomeric effects are not important, a small effort should be made to firmly substantiate this conclusion.

CONCLUSION 12.

The studies on the general pharmocology in different animal species has uncovered interesting chemical structure biological activity relationships.

RECOMMENDATION 12.

It is recommended that the general pharmocology studies be continued to uncover side effects and provide data useful for elucidating mechanism of actions.

[redacted]

[redacted]

WORKING GROUP ON RADIAC REQUIREMENTS
14TH, 15TH APRIL 1969

CONCLUSIONS

1. We conclude that the commanders guides could be applied with the aid of Radiac instruments in service or about to come into service (i.e. in advanced design stage) but we consider there is some uncertainty in the validity of the guides. This uncertainty is due to lack of information on their derivation and the probability that they are based on the table of effects compiled some ten years ago which should be reviewed in the light of information obtained since. We are concerned over the accuracy implied by the guides and its implication for instrument design. Lists of instruments have been compiled and are available from Working Group members.

2. The unit of dose recommended for incorporation in instruments i.e. tissue or water, midline or surface, measured on the body or in air is considered to be not important until such time as the table of effects can be described more accurately. This statement is especially true in recognition of the random orientation of personnel expected when large numbers of exposures occur.

3. At the present time dose rate meters give a measure of dose between the exposure and the midline dose. Dosimeters for γ and n radiations are in advanced stages of design but the prime difficulty is assigning a dose equivalent to the neutrons.

It is our opinion that an indirect reading dosimeter should be a personal issue to all personnel. It can be of value in the tactical sense (if a convenient reader is provided) and can certainly provide a measure of individual radiation exposure when this is required (to determine radiation states for example).

4. We cannot at this time specify the characteristics for ideal dosimeters nor the preferred body location: these subjects remain under study.

[redacted]

THERAPY REGIMES WORKING GROUP
14TH, 15TH APRIL 1969

I. RECOMMENDATIONS FOR TREATMENT OF THERMAL INJURY

The current accepted mode of thermal injury therapy remains stable, but exciting new approaches are being explored in major medical centres. The early results are not yet clinically adaptable for use with mass casualty situations, however.

The following recommendations for therapy are for thermal injuries alone, and no definitive recommendations can be made for treating patients with associated major traumatic or irradiation injuries due to a lack of specific knowledge about their combined effects. This problem is most acute during triage.

1. TRIAGE. Triage principles must be applied to all patients with thermal injuries. The responsibility for triage should reside with the most experienced available person, and the principles are reapplied for each stage of therapy for each patient. The following recommendations are for guidance in "average" mass casualty situations and must vary according to local conditions that may exist at any given time. In addition the association of minor traumatic injuries should not change these recommendations.

a. The "Rule of Nine" should be taught to triage personnel because it is sufficiently accurate to use in the field. No effort should be made to teach the differentiation between partial and full-thickness burns to these persons. Therefore, the percentage burn used in these recommendations refers to the total body surface area burn.

b. Patient Groups:

Group I. 1-20% TBSA Burn. These persons, if in the young adult age group, can be treated by furnishing oral fluids (salt tables and water), giving oral or parenteral narcotics as needed, and making efforts to keep the would clean. They should be given such simple therapy as to provide comfort and to improve their functional capacity. They are not routinely considered for evacuation.

Group II. 21-51% TBSA Burn. These persons should be given first priority in casualty triage. Narcotics and intravenous saline solutions should be started if they are available at a forward treatment area. If not available oral saline solutions should be given until they can be evacuated to a more advanced medical facility. Exceptions to this category are given in sub-paragraphs c and d.

Group III. Above 50% TBSA Burn. These persons should not be considered for therapy until all other patients have been treated. Exceptions would be made for persons whose knowledge and position are such that it is mandatory that every effort be made for them to survive and to continue to function. Narcotics should be used as needed.

c. Effect of Age. It is well known that older patients do not tolerate the burn wound as well as younger patients. Therefore, in general, patients over the age of 50 years should not receive priority in the triage of thermal injuries. This factor must be weighed according to the numbers of casualties, and the personnel, equipment, and supplies available to care for them.

d. Pulmonary damage. Persons with extensive facial or oro-pharyngeal burns should be carefully selected by the triage officer because they fail to tolerate the burn injury due to the extensive pulmonary damage that occurs by inhalation of smoke and/or hot gases. Therefore, a patient showing evidence of this type of injury with severe respiratory difficulty or with a greater than 20% total body surface area burn should not receive top priority for therapy. This factor again must be weighed against the conditions extant at the time or injury.

c. New principles of triage must be applied at the advanced Casualty Centre according to the existing situation.

2. BURN WOUND CARE

a. Initial. Local care of the burn wound at the site of injury should consist of removal of charred and dirty clothing, and wrapping with clean material that will protect the wound. Extensive washing, debridment of blisters, or the application of topical agents is not recommended at this time except for very minor burns wherein local analgesics might be of value when applied to particularly sensitive body areas. No efforts should be made for wound decontamination of radioactive material.

b. Transportation. During transportation efforts should be made to protect the wound from further contamination.

c. Advanced Casualty Centre. This term is used to denote any type of facility that is equipped for surgical procedures. There the burn wound should be cleansed, and, if available, topical chemotherapy should be started. Major attention during this phase of treatment should be directed to the systematic response rather than to the local wound, however. At the present time there is a dearth of active topical ointments that are effective and not prohibitively expensive or bulky. If the supply situation, however, is such that one or more of these agents is available, they should be applied at this time.

d. Definitive. Established principles of eschar removal and skin grafting should be used in major treatment centres when the patient is evacuated to these areas.

3. RESUSCITATION

a. Initial. Patients in Group I should receive an oral saline solution containing the equivalent of 2 Grms of salt per quart or liter of water. Sodium bicarbonate: sodium chloride (1:2) is recommended, but sodium chloride alone is acceptable if the mixture is not available.

For Group II patients it is recommended that a balanced saline solution be administered intravenously immediately after the injury occurs and prior to transportation if packets of the salt are available that can be diluted to the recommended volume with any "purified" water. This does not imply the use of sterile water. The rate of administration should be approximately 1 liter per two hours. Plasma or other types of colloids should not be administered at this time. The above oral solution can be given at double this dose if IV fluids are not available. Oral or parenteral narcotics should be given as needed.

b. Transportation. During transportation the intravenous or oral saline solution administration should be continued.

c. Advanced Casualty Centre. At this point the intravenous or oral fluids should continue to be administered. Greater attention should be placed upon

[redacted]

ambient temperature, the degree and extent of burn, and the total amount of fluids that are needed. At this time it is recommended that plasma or other colloid solutions not be stocked for thermal injuries. There is apparently sufficient evidence to show that the initial resuscitation can be effective using saline solutions only. If available, and not needed for other persons, plasma and/or its substitutes could be used in selected cases during the second 24 hours. At this point antibiotic systemic therapy should also be started depending upon the local bacterial flora and availability of different antibiotics. Penicillin is probably the antibiotic of choice for the usual patient.

d. Definitive. Final resuscitative therapy should be complete within 48 to 96 hours, and further definitive treatment should be given at larger medical centres. Attention should then be directed to the maintenance of nutrition and the treatment of the complications that may occur with this type of injury.

4. REHABILITATION. Efforts should be made in all of the burn injuries to keep these patients functioning, ambulatory, and doing as much for themselves as possible. This principle should be applied from the time of injury and throughout the entire course of treatment. It is realised that this treatment resumè is directed to the potentially salvageable patient, and in most instances they will be able to function and carry out more tasks than patients with more extensive burn wounds. This concept should aid in the rehabilitation and early return to a funcional status of the burn patient.

5. PERSONNEL. All available, trained or untrained, personnel must be used. Group I patients should afford a nucleus of available persons if properly selected.

6. AREAS OF NEEDED RESEARCH. Much information is still needed to improve the treatment of these patients. This section will briefly list the areas of needed research in the phases of thermal wound care that should have established priorities. The following sections are not presented in a suggested order of priority.

a. Immediate Wound Coverage. A light, easily packaged, and sterile material should be available to afford protection to the burn wound at the time of initial cleansing and during transportation. Logistic problems, porosity, heat transmission properties, and sterilising methods should be investigated.

b. Resuscitation Therapy. Further information should be available concerning the efficacy of different types of fluid using during the resuscitative period. Controversy continues to rage about the problem of saline versus colloid replacement therapy. A plasma or colloid solution should be available in a dry form (suitable for reconstitution and use) at the advanced casualty centres.

c. Pulmonary Damage. Improved substances and techniques should be available for therapy for pulmonary damage. There exists a definite lack of understanding concerning the pathological biochemical and functional changes that occur in the burned lung, with and without direct injury. More information is definitely needed to improve survival.

d. Eschar Treatment and Removal. This remains a major problem. A rapid method for the removal of burn eschar shortly after burning should be developed, and at the same time a readily available skin substitute should be available. This "skin substitute" must be lightweight, flexible, water-protective, and bacteriostatic. It must also be fairly non-reactive to the underlying tissues. In addition, prior to the following the possible

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removal of the burn eschar, improved chemotherapeutic agents with a wider range of effectiveness should be searched for that can be easily stored in dried bulk form and reconstituted at the advances casualty centre. Improved grafting methods should continue to be investigated, although the use of these is most applicable at definitive care centres.

e. Cellular Response to Injury. Further basic research is needed in the fields of the sub-cellular and cellular response to injury, the response of the immune system to injury, and the effect of "catabolic-protective" agents upon the injured patients. These are wide fields of endeavour and deserve intensive investigation.

f. ProphylacticVaccination. Enlarged clinical trials should be conducted to determine the efficiency of vaccinating "high risk" persons against suitable pathogenic bacteria, ie pseudomonas aeruginosa. Improved antigens and techniques for use are also needed.

g. Anti-inflammatory and analgesic agents. No effective local or systemic anti-inflammatory agents are available and, in selected clinical situations, they could be very useful. Narcotics are generally unsatisfactory when used to treat "burn pain", and they also have undesirable side effects. Active research for new compounds with these properties should be pursued.

h. Performance Decrement - Human. Clinical data should be obtained re extent and type of injury effect upon performance under different stress situations.

II. A SIMPLE PLAN FOR DIAGNOSIS AND THERAPY OF THE ACUTE RADIATION SYNDROME.

This presentation summarizes the current status of diagnosis and therapy of the acute radiation syndrome under two circumstances, 1) that in which there are minimal or no facilities for care, and 2) that in which some facilities are available both for diagnosis and treatment. Finally a few suggestions for additional research will be proffered.

1. ACUTE RADIATION INJURY UNDER MEDICALLY AUSTERE CONDITIONS

a. Classification and Clinical findings. The concepts presented here are taken from a committee report chaired by M. Ingram which although done for civil defense purposes gives useful information for other purposes. (1)

The degree of radiation injury would have to be estimated on the basis of clinical observations even though some radiation detection devices might be available. The amount of shielding at the time of a detonation would have to be obtained by individual patient history as would subsequent exposure to fallout. Concurrent injury and disease would also be significant factors when present.

Radiation injury is usually classified by five injury groups as shown in Table 1 slightly modified from (2). It is divided into four stages as shown in Table 2 (3) for austere conditions. Under these conditions the salient characteristics of clinical manifestations and leukocyte picture following various degrees of injury are summarized in Table 3 (1). For this situation Patient Group V is omitted from consideration since such individuals could not be offered any therapy.

The observations of Table 3 are those following a single short term exposure. Factors which can modify the individual response and which can be elicited by history and physical examination are given in Table 4.

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Recording of symptoms and signs in a standardized way simplifies the grouping of each individual particularly if the time of each observation is recorded. The relevant symptoms and signs for the prodromal and manifest illness stages are given in Tables 5 and 6, (3). It is essential to record the length of the latent period. The rapidity at which these occur and their severity will serve as a guide to the severity of radiation injury (4).

Combined injury may possibly occur under conditions of actual warfare although the importance of these kinds of injuries is minimized by some acknowledged experts on this subject. If such situations should occur clinical description of degrees of radiation injury may become misleading.

There is likely to be an unduly high index of suspicion with respect to radiation injury as a cause of any gastrointestinal symptoms, malaise and fever. It is particularly important to reserve judgement about the degree of radiation injury in acutely ill patients, who have sustained severe burns, fractures and the like. Severely burned patients will probably become nauseated and vomit; so may patients with fractures. Shock may obscure the symptoms and clinical signs of radiation injury in the severely traumatized patient. Little information about acute radiation injury in infants and children is available, hence a high degree of caution in accepting nausea, vomiting and diarrhoea as infallible signs of severe radiation injury is indicated when evaluating pediatric patients. An objective attitude about the relative importance of radiation as a cause of observed symptoms would help allay patients' anxiety when it stems from fear of radiation injury. Nevertheless in our studies (5) we have not observed vomiting from sham irradiation. In recent severe combat experience vomiting was not associated prominently with psychic stress.

b. Triage. Where radiation contributes significantly to injury, triage based on the above findings becomes the most important task of the medical officer in the first days and weeks especially if there are no medical facilities. His responsibility is to preserve the health of Group I and II patients so that they may survive and return to their duties. They are the ones for whom food, fluids and best sanitation efforts need be directed. The limited emergency supplies could in no way affect the levels of morbidity or mortality of Group III-V individuals in this situation. Particular care need be directed towards limiting care of other injuries in these latter categories.

The following rules of triage for radiation are recommended:

1. No evacuation for radiation injury shall be carried out within the first 24 hours except for controlled vomiting.

2. Those individuals who show lessening in frequency of vomiting at the end of 48 hours can then be evacuated.

3. Those individuals with intractable vomiting within the first 48 hours should not be evacuated or receive therapy.

c. Laboratory aids. If any simple laboratory test were available the most desirable would be simple white cell counts and absolute lymphocyte counts. The typical findings of the white cell count for various dose levels are shown in Figure 1 (4). The use of the absolute lymphocyte count in the first 48 hours is of particular value and the findings are illustrated in Figure 2 (6).

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d. Therapy. Treatment is limited to rest, adequate fluids and foods and maintenance of personal hygiene to the degree possible. Tranquilizers, medicines for other complaints and antibiotics are highly desirable if available.

2. DIAGNOSIS AND TREATMENT WHERE FACILITIES ARE MORE ADEQUATE

With somewhat more elaborate facilities - field or stationary hospitals and some available medical and paramedical personnel - both diagnosis, triage and therapy can be improved. In this circumstance five injury groups may be considered. Until recently Group V was considered to be due to central nervous system changes. Recently Fanger and Lushbaugh (7) have described two cases of death following high radiation doses with a mechanism of cardiovascular shock as well as clinical CNS changes. Pathological changes of the central nervous system were minimal, however.

With adequate haematological service a somewhat more predictive method of evaluation can be utilized (Figure 3) (8). If a large number of patients are to be managed, the relevant examinations should be carried out as shown in Table 7 (3).

Therapeutic considerations should be directed toward problems associated with neutropenia whenever possible. Under conditions of grave emergency, possible isolation, careful skin care, systematic antibiotic therapy, triple antibiotic therapy to injection site and nares, and bowel and staphyloccal prophylaxis can be considered to some degree. Disruption of the intact skin and mucous membrane should be avoided. Rectal temperature and gastric intubation should be avoided.

Bowel sterilization can be done as follows:

Neomycin 1 gram PO q 6 hr
Oxacillin 500 mg PO q 6 hr
Nystatin 500,000 units PO q 6 hr

Staphyloccal Prophylaxis

Bacitracin to nares
Oxacillin 500 mg q 6 hr

If elaborate facilities become available for selected patients the following measures should be considered on admission: reverse isolation, screening blood tests and cultures, monitoring for radioactivity, daily haemogram, daily bath, stool softener, daily vitamins especially Vitamin C, daily weight, no aspirin.

During the critical stages the reverse isolation is strict with no visitors. Additional measures include canned food, bedrest to avoid trauma, tests for blood in faeces and urine, oral antibiotics as needed, adequate fluids, recording of urinary output, avoidance of bed sores. Bone marrow transfusion at present seems of practical value only in identical twins.

A few recommendations concerning future research are made:

1. Dose rate studies - Information is lacking as to whether very high dose rates would produce a more severe clinical episode than would low dose rates. An allusion to this problem occurs in connection with Table 3.

2. Influence of diet - In spite of many studies on the intestinal flora and their relation to many manifestations of acute radiation injury, we lack information as to whether to provide human beings with high or low residue diets or with changes in balance between fat, carbohydrate or protein.

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3. Study should be made of the most appropriate fluid therapy for radiation casualties. Possibly the saline solutions recommended for thermal casualties could usefully be employed.

4. Immune systems - Further implications of work with immunosuppressive agents should be analyzed with a view towards relating these methods to allografts of bone marrow. Studies of lymphocytes and stem cells to develop transplantable cultures with specific immune capabilities would be a consideration.

5. Typhoid-paratyphoid A and B vaccine should be investigated as a stimulant for haematopoietic recovery in man. Other agents producing a similar effect should be studied.

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TABLE 1

RADIATION INJURY GROUPS

Group I: Less than half this group vomit within 24 hours after the onset of exposure. There are either no subsequent symptoms or, at most, weakness and easy fatigue. There is a decrease in the white blood cell count (which is most marked in the case of lymphocytes) and in the platelet count. Less than 5 per cent (1 out of 20) require medical care. All others can perform their customary tasks. Any deaths that occur are caused by complications. Sickness of this type has been seen after brief, whole-body doses of gamma and X-radiation in the range of 50-200 R. An ERD of external gamma radiation of 50-200 R may have a similar effect.

Group II: More than half this group vomit soon after the onset of exposure and are sick for a few days. This is followed by a period of 1-3 weeks when there are few or no symptoms. During the latent period, typical changes occur in the blood count and can be used for diagnosis. At the end of the latent period, epilation (loss of hair) is seen in more than half, and this is followed by a moderately severe illness due primarily to the damage to the blood-forming organs. Most of the people in this group require medical care. More than half will survive, with the chances of survival being better for those who received the smaller doses. Sickness of this type has been seen after brief, whole-body doses of gamma or X-radiation on the order of 200-450 R. An ERD of external gamma radiation of the same size will probably cause a similar illness.

Group III: This is a more serious version of the sickness described as Group II. The initial period of illness is longer, the latent priod is shorter, and the main episode of illness is characterized by extensive hemorrhages and complicating infections. People in this group need medical care and hospitalization. Less than half will survive, with the chances of survival being poorest for those who received the largest doses. Sickness of this type has been seen after brief whole-body gamma radiation with doses in excess of 450 R. It is possible that an ERD of external gamma radiation of the same size will have a similar effect.

Group IV: This is an accelerated version of the sickness described as Group III. All in this group begin to vomit soon after the onset of exposure, and this continues for several days or until death. Damage to the gastrointestinal tract predominates, manifested by intractable diarrhea, which soon becomes bloody. Changes in the blood count occur early, and within a few days the total white cell count may be less than 500 per mm. Death occurs before the end of the second week, and usually before the appearance of hemmorrhages or epilation. All in this group need care, and it is unlikely that many will survive. Sickness of this type has been seen after brief, whole-body exposure to gamma radiation in excess of 600 R. During protracted exposure to external gamma radiation, it is not probable that an illness of this type would be the first evidence of injury.

Group V: This is an extremely severe illness in which damage to the brain and nervous system predominates. Symptoms, signs, and rapid prostration come on almost as soon as the dose has been received. Death occurs within a few hours or a few days. Sickness of this type has been seen after a brief whole-body exposure to gamma rays in excess of several thousand R and to equivalent doses from neutrons. Cardiac failure may well play a role in the changes observed in this category.

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TABLE 2

CLINICAL STAGES OF THE ACUTE RADIATION SYNDROME

		approximate duration
1.	Initial or prodromal stage	0 to 48 hours.
2.	Latent stage	2 to 3 weeks.
3.	Manifest illness stage	2d or 3d to 6th week.
4.	Recovery stage	8 to 15 weeks.

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TABLE 3

LABORATORY AND CLINICAL OBSERVATIONS

(Single Short-Term Exposure)

Degree of Injury	Nausea	Vomiting	Diarrhea	Fever	Description of available laboratory data if available: Lymphocytes (per mm3 at 48 hrs or later)	Total Leukocytes (per mm)
Patient Group I	±	±	0	0	not lower than 800	minimal change
Patient Group II	++	++	±	±	not lower than 400	neutrophils variable on days 1 and 2; decreased to about 3000 by days 5-10
Patient Group III **	+++	+++	± to +	+	not lower than 200	transient rise in neutrophils and total WBC count within few hours followed by precipitous drop to about 1000/mm3 at 10 days
Patient Group IV*	++++	++++	++++	++++	< 200	greater neutrophil and WBC increase, then a fall to less than 1000/mm3 in less than 1 week.

* The severely injured patients in Patient Group IV would have an extremely poor prognosis and therapy other than that for relief of symptoms would not be indicated.

** Vomiting in Group III may be expected within the first 6 hours.

TABLE 4

FACTORS MODIFYING RESPONSE TO RADIATION

1. Location of subject, degree of shielding, exposure, kind of shielding, immediate subsequent action.

2. Evidence of other injury.

3. Prior or concurrent disease.

4. Prior and subsequent physical activity.

TABLE 5

SYMPTOMS AND SIGNS FOUND IN PRODROMAL STAGE OF ACUTE RADIATION SYNDROME

Anorexia	Prostration
Nausea	Diarrhea
Vomiting	Abdominal pain
Weakness & fatigue	
Conjunctivitis	Sweating
Erythema	Oliguria
Fever	
Hyperesthesia	Paresthesia
Ataxia	Coma
Disorientation	Death
Shock	

TABLE 6

SYMPTOMS AND SIGNS FOUND IN MANIFEST ILLNESS STAGE OF ACUTE RADIATION SYNDROME

Anorexia	Sweating
Nausea	Oliguria
Vomiting	Weakness & fatigue
Diarrhea	Prostration
Abdominal pain	Weight loss
Abdominal distention	Hyperesthesia
Conjunctivitis	Paresthesia
Erythema	Ataxia
Jaundice	Disorientation
Fever	Shock
Infection	Epilation
Purpura	Coma
Hemorrhage	Death
Scalp pain	

TABLE 7

RECOMMENDED DIAGNOSTIC PROCEDURES FOR CLINICAL MANAGEMENT OF RADIATION INJURY

	GROUP										
	I-II-III-IV			I	II			III		IV	V
	1	2	3	STT	STT	18-43	STT	4-48	STT	4	1
Type A Procedures											
History											
Symptoms) onset	x	x	x	x	x	D	x	D	x	D	D
Signs) duration	x	x	x	x	x	D	x	D	x	D	D
Past Medical	x										
Physical Examination											
General						d21	3mo+	d15-30	6mo+	d6	D
Body Weight	x			x	x	D	x	D	x	D	D
Urinary output	x	x	x		x	D		D		D	6hr
Laboratory Tests											
Hematology											
Hematocrit	x	x	x	x	x	D	x	STT	x	D	6hr
Leucocytes	x	x	x	x	x	D	x	D	x	D	6hr
Differential Count	x	x	x	x	x	D	x	D	x	D	6hr
Calculation of Total Neut. and Lymph	x	x	x	x	x	D	x	D	x	D	6hr
Platelets	x	x	x	x	x	D	x	STT	x	D	6hr
Bone Marrow Aspiration				d30	14d	14d	mo6	14d	mo6	7d	d1
Radioassay											
Blood Na^{24}	x	x									
Whole Body Counting	x	x									
Type B Procedures											
Laboratory Tests											
Hematology											
Sedimentation Rate	x	x	x	x	x	D	x	D	x	D	6hr
Reticulocytes	x	x	x	x	x	D	x	STT	x	D	6hr
Bleeding) Times Clotting)	x					STT		STT	-75d	3d	6hr
Biochemistry											
Blood											
NPN	x	prn	prn					prn		STT	6hr
Sodium	x	prn	prn					prn		prn	d1
Chloride	x	prn	prn					prn		prn	d1
Potassium	x	prn	prn					prn		prn	d1
pH or CO_2	x	prn	prn					prn		prn	d1
Urine											
Routine analysis	x	x	x		x	D	x	D	x	D	6hr
Stool											
Occult Blood	x					D		d12+		D	All
Opthalmology											
Slit lamp			x	6mo+			6mo+		6mo+		
Type C Procedures											
Biochemistry											
Serum bilirubin	x	x	x		x	STT		STT	-30d	D	6hr
Urine BAIBA	x			-30d	x	D		D		D	D

RECOMMENDED FREQUENCY OF TIME OF PERFORMANCE

STT = Standard Testing Times: 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 40, 44, 48, 60, 90, 105, 120 days; 6 months; 1 year and annually
x = at times indicated in column heading
d = day(s)
D = daily during time indicated in column heading
nD = frequency in days
-Dn = up to and including day at times indicated in column heading
Dn+ = on and after day at times indicated in column heading
Dn = specific day recommended
n = all times after day specified
prn = as indicated by clinical course

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FIGURES 1(a) and 1(b)

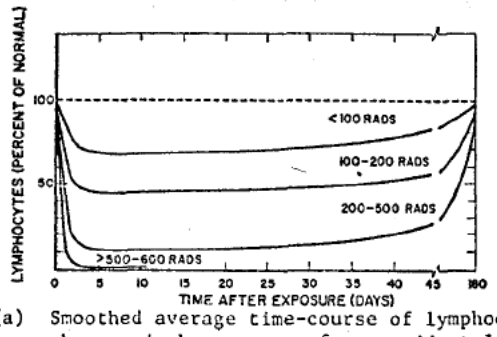

Figure 1(a) Smoothed average time-course of lymphocyte changes in human cases from accidental radiation exposure as a function of dose.

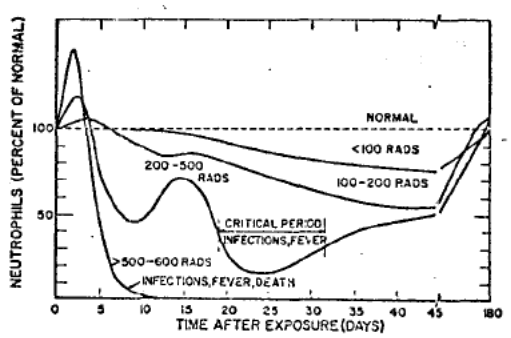

Figure 1(b) Smoothed average time-course of neutrophil changes in human cases from accidental radiation exposure as a function of dose.

FIGURE 2. Schematic relationships between lymphocyte levels and dose.

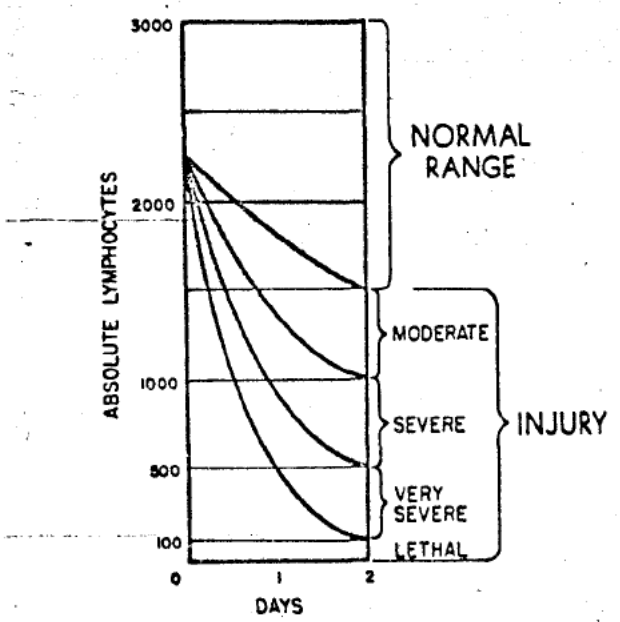

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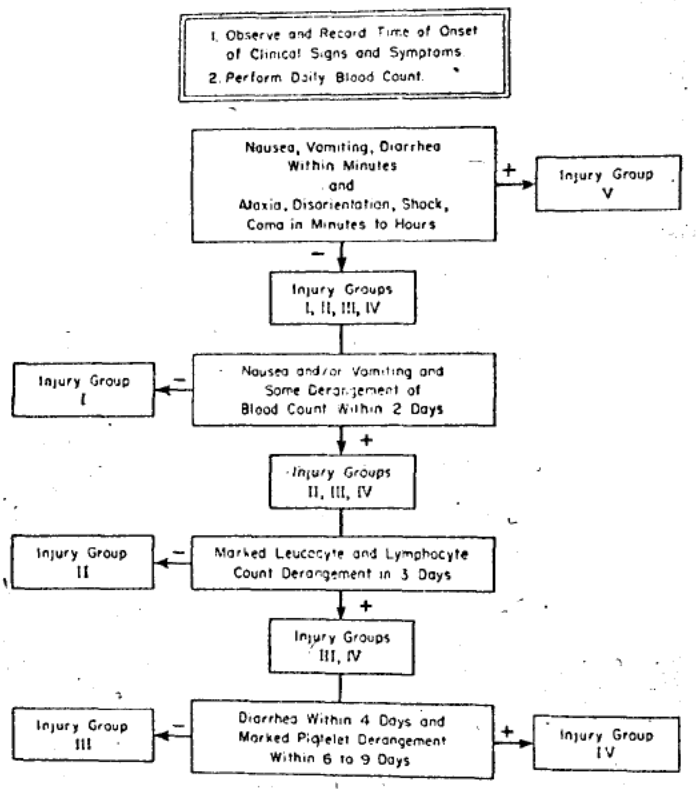
FIGURE 3. Preliminary Evaluation of Clinical Radiation Injury Following Overexposure.



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III. RECOMMENDATIONS FOR TREATMENT OF HUMAN DIRECT (PRIMARY) BLAST INJURY.

In order to define therapeutic procedures which might be used in blast-injured individuals, it is first necessary to understand some of the physical and biological aspects of this type of injury. Certain physical properties of the blast wave are biologically important:

1. Rise Time:

If dogs are exposed to fast-rising wave forms of a 30 millisecond duration, the LD_{50} is experimentally found to be 49 psi. If, however, a rise time of 150 milliseconds precedes the 30 millisecond fall, such as might occur in structures with relatively slow fill time, dogs can experience pressures of 167 psi with little apparent damage.

2. Duration:

The LD_{50} for dogs exposed to a fast-rising wave of 1 millisecond duration is 250 psi. If, on the other hand, the wave is fast-rising but has a duration of 30 milliseconds, the LD_{50} is 49 psi. A characteristic duration of any nuclear weapon can be considered to be long for man.

3. Reflection:

An incident shock wave of 15 psi reflects to 42 psi against a rigid, non-yielding surface. Therefore, a dog exposed to a free-stream shock wave of 15 psi might experience eardrum rupture and minimal lung damage. Whereas, if the subject is against a reflecting surface, severe lung damage might be expected.

4. Step Load:

An animal against a reflecting surface experiences the incident and reflected shock wave at virtually the same time. However, if the subject is placed a short distance from the reflecting surface, the delay between the incident and reflected wave can be highly significant. In the case of small animals, a 0.2 millisecond separation can produce an increase in tolerance of approximately 50 percent: whereas in the case of rabbits, a similar increase is seen with a 0.8 millisecond delay.

Biological Effects:

Over the past 17 years, Lovelace personnel have investigated various biological aspects of air blast. Studies have been performed to determine the air blast tolerance of 13 animal species, ranging in size from mice to burros. Psw equal to reflected pressure of a square wave resulting in 50 percent survival at a PO of 14.7 psi, range from 30.8 for the guinea pig to 71.9 for the burro. Individual species tolerance was generally found to be related to the body mass and two distinct curves were found to exist for large animals (dog to burro) and small animals (mouse to rabbit). The average Psw for large species was found to be 61.5 psi and since man, on the basis of body mass, would be expected to behave like one of the large animals, this mean value was taken as the LD_{50} for human beings. By using established scaling principles, 1 through 99 percent survival estimates were established for man as a function of reflected overpressure and pressure duration (Fig. 1). Similar estimates were prepared for several body orientations, such as free-stream situations where the long axis of the body is parallel to the direction of the propagation of shock blast wave, and free-stream situations where the long axis is perpendicular to the direction of the propagation of the shock blast wave (Figs. 2 and 3). These represent our current best estimates.

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An important by-product of this extensive investigation has been the delineation of principle forms of injury which result from exposure to air blast. When a blast wave of long duration strikes the body, it results in compression of the chest and subsequent rebound. Most of the injury results from shearing due to the differential acceleration of tissues of different density. The greatest impact, therefore, is on air-bearing structures such as the lung, G.I. tract, sinuses, and ears. The lungs represent the primary and most important organ system effected by primary blast exposure. The characteristic findings consist of ruptured alveolar septa with subsequent emphysema and intrapulmonary hemorrhage. Frequently, retrograde blood flow extends into the bronchials and major bronchi. One of the most frequent areas of intrapulmonary disruption occurs at the interfact between alveoli and the large pulmonary bronchi and vessels. Torn veins in such locations probably represent the source of systemic air emboli. Additionally, the bronchial epithelium is frequently stripped by the shearing force attendant with air blast exposure. The combination of intrapulmonary hemorrhage and the subsequent development of pulmonary edema results in a distended heavy lung with a lung to body weight ratio of 2 percent or more, as contrasted to normals of less than 1 percent. Variable areas of gross hemorrhage can be observed, particularly in the lower lobes and at higher pressures, linear subpleural areas of hemorrhage are present which result from impact of the intercostal soft tissue on the pleural surface.

In animals that die within the first five to ten minutes, pulmonary edema generally has not developed but a frequent finding is the presence of air emboli in coronary, cerebral and mesenteric arteries. Later deaths, 30 minutes and beyond, are associated with severe pulmonary edema and continued intrapulmonary hemorrhage with signs of severe anoxia. In subjects that survive, restoration of normal lung appearance occurs quite rapidly so that by approximately 7 days post-exposure hemosiderin is the only landmark of previous hemorrhagic areas.

The gastroenteric tract is also frequently effected, particularly the air-containing structures. The cecum, colon, stomach, and ileum show serosal and sometimes mural hemorrhage which extends into the attached mesenteric. At very high pressures, rupture of the spleen, liver or a hollow viscus is a frequent finding.

Certain delayed sequelae have also been observed. In one group of sheep exposed to near P-50 levels, 50 percent of the animals surviving for 60 days showed varying degrees of myocardial infarction. It is uncertain at this time whether these ischemic areas result from air embolic occlusion of coronary vessels or from coagulation disorders associated with this type of trauma. Mild myocytolysis has been observed as early as 5 minutes following blast exposure but is generally only discernible when viewed with ultraviolet light. Similarly in the kidney, infarcts have been observed in 75 percent of this same group of sheep. These renal infarcts have ranged from 2 millimeters in size up to near ablation of the entire organ. The distribution of infarcts appears to be random and fibrin thrombi have been observed in non-survivors dying as short as 5 minutes post-exposure. Although not established, the hypertension observed in the Texas City disaster victims may well have resulted from such renal ischemic changes. In addition to sheep, such lesions have been observed in cattle, swine, goats and dogs.

One additional interesting clinical feature of blast injury is the precipitous drop in lymphocytes and platelets. In the case of lymphocytes, this seems to be dose-related and is probably due to a stress phenomenon mediated through the adrenal cortex. A 60 percent drop in lymphocytes has been observed as early as 15 minutes following exposure at near P-50 levels. Platelet depression, although less obviously dose-related, also occurs within 15 minutes, the magnitude being in the order of 40 percent at higher pressure levels. During the same time period

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agranulocytosis is frequently observed and is probably related to an adrenal-medullary response to trauma. Some species variability has been seen in terms of response with monkeys, showing both a lymphocytosis and granulocytosis.

Clinical Picture:

Most of the information relating to mans' response to air blast is derived from experience gained during the Spanish War and Second World War. Initially, blast victims are lethargic to comatose. In the absence of impact or secondary missile trauma, there is frequently little external evidence of the degree of internal injury. The most common earmark is the presence of blood-tinged froth or frank blood around the nose and mouth. The respiration is initially shallow and rapid. As time progresses, air hunger becomes progressively more evident and occasionally disturbances in equilibrium, convulsions, and focal paralysis have been seen. A paradoxical form of shock is evident in that bradycardia is initially associated with the hypotension and as time progresses, the cardiac rate increases. This is probably mediated through a vagal reflex. Death may occur rapidly due to cardiac erythemas and if such does not occur,, the patient may succumb at a later time from congestive failure and the development of pulmonary edema. Victims surviving beyond the first 30 minutes complain of tightness across the chest and also costochondral junction pain. Pleural, abdominal and chest pain may also result from the presence of pleural or peritoneal hemorrhages. The cerebral signs abate rather slowly, but permanent sequelae are generally not seen.

Hazards during the first week post-exposure include the development of pneumonia or lung abscess, rupture of an emphysematous bleb with pneumothorax or emphyema, the development of peritonitis from a ruptured hollow viscus, and the development of a hematoma or generalized bleeding into the peritoneal cavity from laceration of the liver or spleen.

Current Suggested Therapeutic Approach:

Position:

Following recovery from the disaster area, the patient should be placed in a mid-left lateral prone position with the head low. This will allow drainage of the airways and will help avoid migration air emboli to the brain and heart. If signs of venous distention develop, elevation of the head and upper trunk may be necessary.

Rest:

Rest is mandatory to keep the workload on the heart and lungs at a minimum during early convalescent periods. Reoccurrence of lung hemorrhage has been recorded up to five days following exposure and periodic hemostasis as long as seven to ten days after injury. The increase in respiratory rate and excursion associated with activity during the critical stage might also dislodge blood clots and re-establish alveolar venous connections which result in air embolic phenomenon. If complete early rest is not possible and some activity is essential to life, such activity should be delayed for a long as possible.

Antitussives, Sedatives, Analgesics and Narcotics:

It is essential that coughing be kept at a minimum to prevent cough-associated high intrathoracic pressures. This should be controlled by antitussive agents, including narcotics if necessary. In addition, sedatives and analgesics may be useful in providing for the rest and comfort of the patient.

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Oxygen Therapy:

The presence of intrapulmonary hemorrhage and edema from blast injury results in a decrease in ventilation with subsequent increase in venous admixture and a decrease in oxygen saturation. Although in severe cases this cannot be completely corrected by administering 100% oxygen, any increase in the amount of oxygen may be helpful and indeed lifesaving. Administration of oxygen also serves a second useful purpose in that it may provide sufficient oxygen to the collateral circulation to minimize the physiologic consequences of air embolic occlusion of critical vessels.

Intravenous Fluids, Whole Blood or Plasma:

These should be employed with great caution in any patient suspected of receiving significant intrapulmonary blast injury. The danger of overloading the already compromised cardiopulmonary system is significant and unless clear evidence of blood loss or plasma loss is present, such agents should probably not be utilized.

Digitalization:

Heart failure, often associated with marked intrapulmonary edema, is a major hazard faced by blast casualties. In certain instances, fulminating cardiac insufficiency has been recorded as long as five days after injury. The use of an intravenous cardiac glycoside may therefore be a lifesaving measure and, in the presence of a neck vein distention, may be employed in combination with venous section.

Other Measures:

Pneumothorax has been recommended as a last ditch measure to control continued pulmonary hemorrhage in stubborn cases. Antibiotics have also been employed in treating blast casualties in order to prevent the development of or control pneumonia and other infections. The use of alcohol was employed by the Germans during the Second World War. A 30% solution, slowly infused, in doses of 30-40 cc proved effective in promoting diuresis, as an anesthetic agent, and possibly resulted in dilation of coronary and peripheral vessels.

Areas for Future Study:

Pressurization:

Immediate pressurization following blast injury has been investigated by Benzinger, Clemedson, and the Lovelace group. The rational being that death from air embolic occlusion of critical vessels might be prevented by reducing the size of circulating air bubbles. In the case of guinea pigs, the Lovelace group found that death could be delayed by placing animals immediately following exposure in a hyperbaric chamber at 72 psig. Utilizing air, this resulted in a PO2 of 17.5 However, total lethality following treatment approached that seen in untreated animals. In a second study, it was found that elevating the PO2 to 12 psi, in the absence of high internal pressures in the chamber, resulted in a similar increase in mena survival time. Subsequently, in studies utilizing rabbits as the experimental subject, these observations were confirmed and by extending the decompression times it was possible to save all rabbits treated at either six atmospheres with a PO2 of 17.5, or one atmosphere with a PO2 of 17.5. This indicates that air oxygen mixtures in combination with hyperbaric therapy might be effective in the case of human blast victims. Future studies utilizing dogs should provide additional information in regard to the efficacy of this form of therapy.

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Anticoagulants, Blood Constituents and Transfusions:

Immediately following a variety of traumatic injuries, including impact, burns, severe lacerations, and air blast, there occur certain abnormalities in the coagulation mechanism. Such changes are characterized by a hypercoaguable state in which occurs sludging of blood and the development of fibrin thrombi. Such thrombi may be responsible for the previously described myocardial and renal infarcts associated with blast injury. It is suspected that the occurrence of this hypercoaguable state might contribute to the development of irreversible shock. Although, on first thought, the use of anticoagulants in injuries associated with hemorrhage might appear contraindicated, judicial treatment might prove highly effective, both in regard to immediate injury as well as preventing the late sequelae. Future plans call for the investigation of this mode of therapy in dogs exposed to air blast. Finally, additional information is needed in reference to the combination of therapeutic measures which might be most beneficial in the treatment of blast injury. This includes, in addition, the measures previously mentioned, the use of bronchial dilators or cold detergent aerosols in promoting pulmonary clearance and thus providing for improved ventilation.

For additional comments and references, see the following two publications:

1. White, C.S. and D. R. Richmond, "Blast Biology," Clinical Cardiopulmonary Physiology, Grune & Stratton, Inc., 1960, pp. 974-992.

2. White, C. S., "Rationale of Treatment of Primary Blast Injury to the Lung," minutes of Panel N-5, Effects on Personnel, Subgroup N, The Technical Cooperation Program, Brooks Air Force Base, Texas, May 28, 1968.

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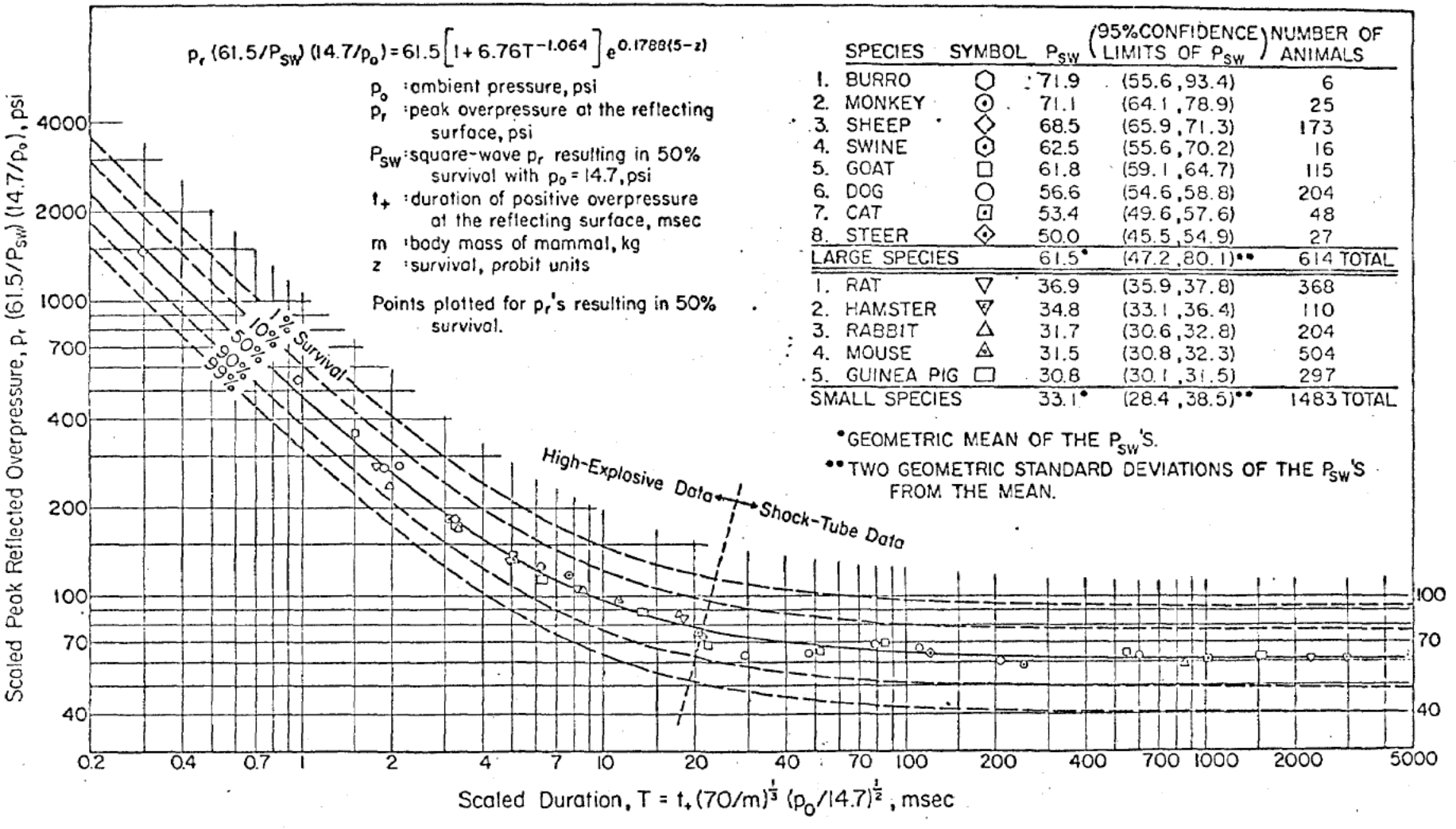

Figure 1. Survival curves, (24-hour) applicable to sharp-rising blast waves, derived from the analysis of data for 12 mammalian species (excluding guinea pig). See text for explanation of plotted points.

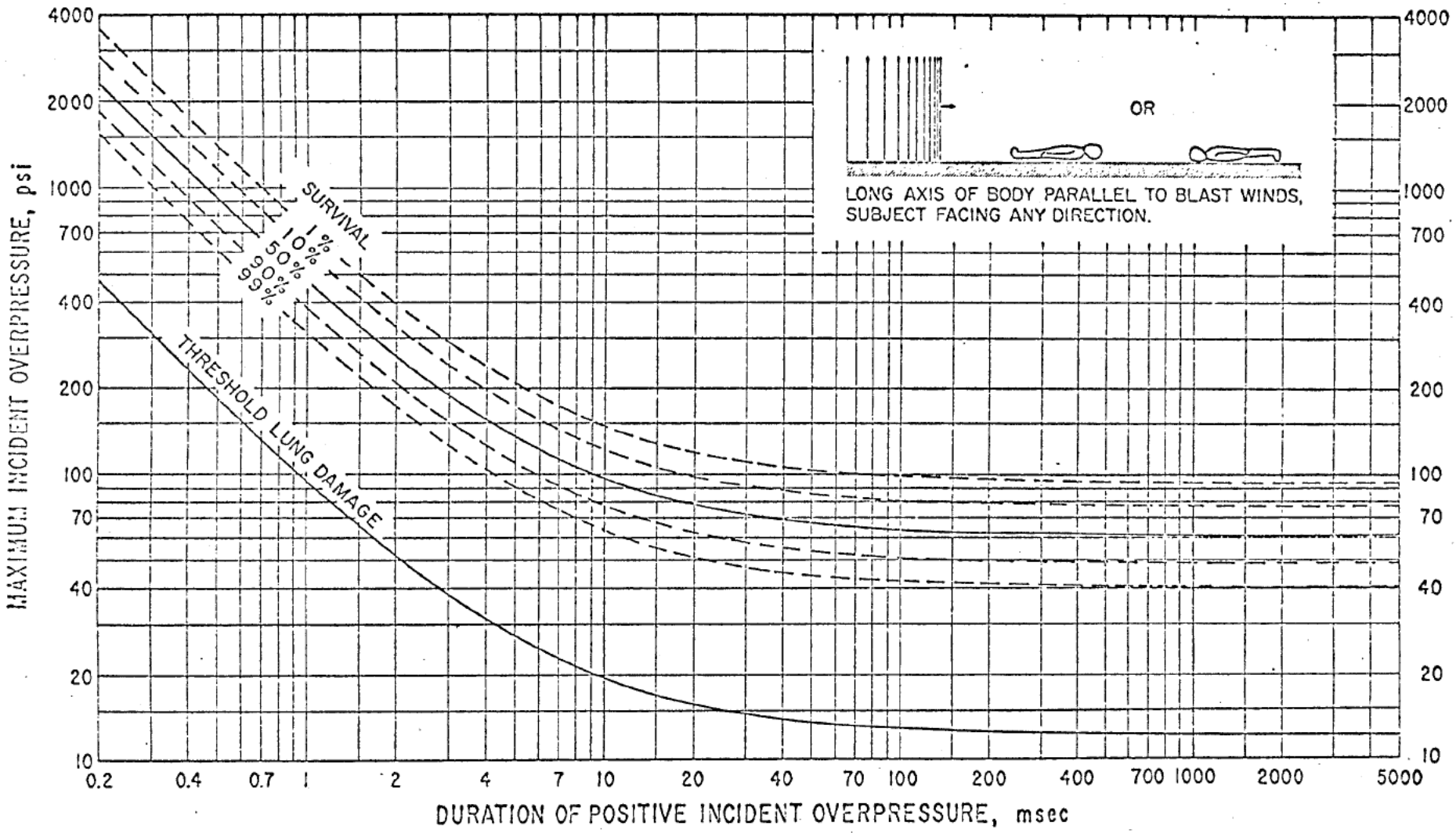

Figure 2. Survival curves predicted for 70-kg man applicable to free-stream situations where the long axis of the body is parallel to the direction of propagation of the shocked blast wave.

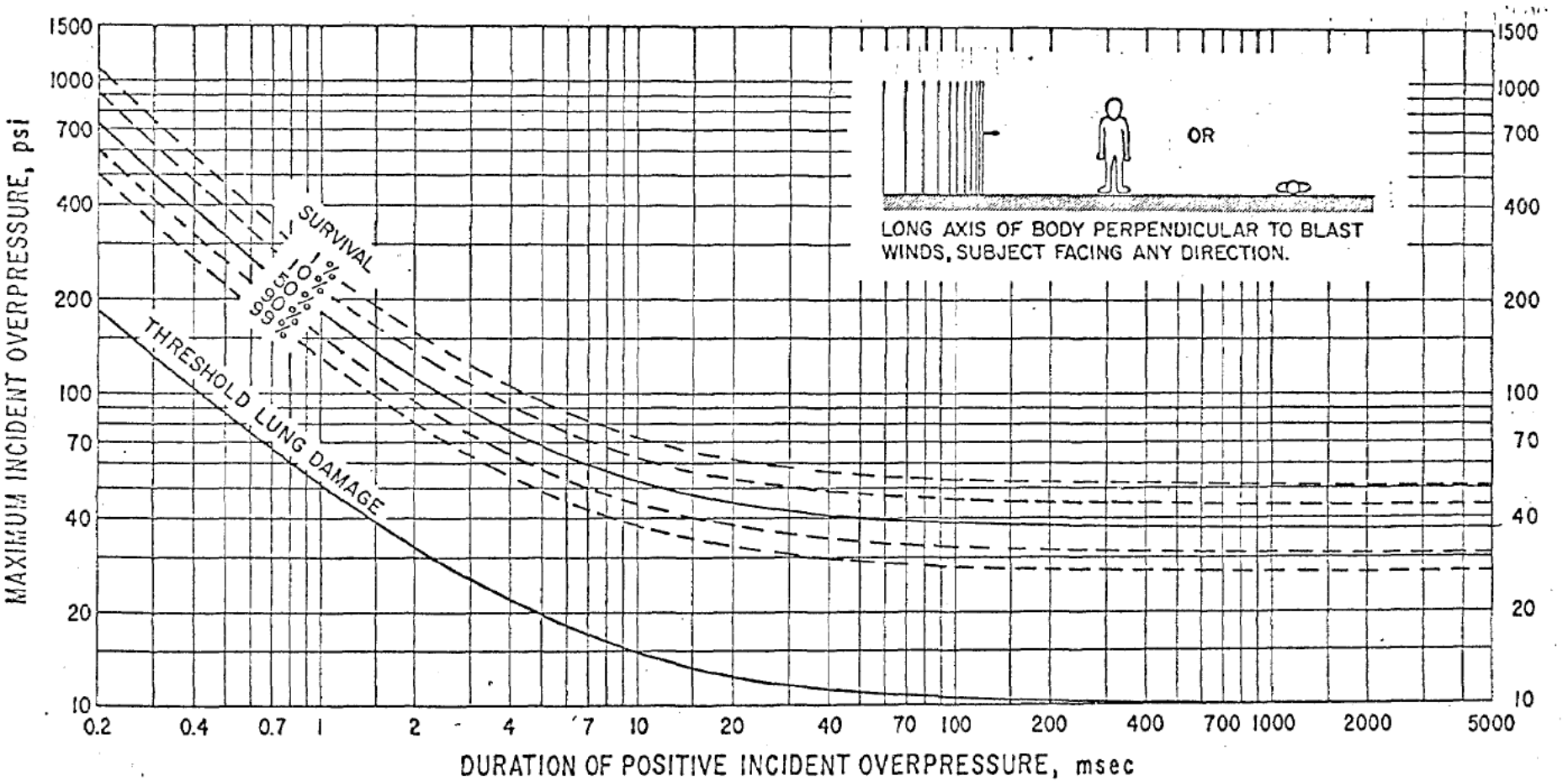

Figure 3. Survival curves predicted for 70-kg man applicable to free-stream situations where the long axis of the body is perpendicular to the direction of propagation of the shocked blast wave.