TECHNICAL REPORT
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業 績 報 告 書

OUTCOME OF PREGNANCY IN WOMEN EXPOSED TO THE ATOMIC BOMB IN NAGASAKI

長崎における原爆被爆女性の妊娠結果

JAMES N. YAMAZAKI, M.D., STANLEY W. WRIGHT M.D., AND
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ATOMIC BOMB EXPOSURE AND THE PREGNANCIES OF BIOLOGICALLY RELATED PARENTS

原爆被爆と血族関係のある両親における妊娠

A PROSPECTIVE STUDY OF THE GENETIC EFFECTS OF IONIZING RADIATION IN MAN

人間における電離放射線の遺伝的影響に関して将来へ向って行なう研究

WILLIAM J. SCHULL, Ph.D. AND JAMES V. NEEL, M.D., Ph.D.

ATOMIC BOMB CASUALTY COMMISSION
原爆傷害調査委員会
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Investigation on animal fetuses and clinical studies of postconception pelvic irradiation have demonstrated a damaging effect of radiation upon the development of the fetus.[1-22] This paper presents a report of investigations being made on the effects of the atomic explosion on fetuses of women who were in Nagasaki on Aug. 9, 1945.

動物の胎児に関する研究，および懐妊後の骨盤照射の臨床的研究は，胎児[1-22]の発育に対し放射線が損傷的影響を与えることを証明した。この論文は，1945年8月9日長崎で被爆した婦人の胎児に対する原子爆発の影響について行なわれた調査の報告書である。

COLLECTION OF DATA

A. Patient Selection. This study was conducted in Nagasaki during the first half of 1951. On the basis of information obtained from the pregnancy records of the genetics program, lists were made of all women who, at the time of the explosion, were of childbearing age (for the purposes of this study, 17 to 50 years of age) and were residing in Nagasaki. A home investigation was done by trained personnel to determine if the mother had been pregnant at the time of the bombing. Conception was considered to have occurred two weeks after the last normal menstrual period.

Since the traumatic and radiation effects of the bomb have been found to be maximal within a 2,000 meter radius,[52] women within this area who were pregnant at the time of the explosion were selected to compose the radiated group. From a total of 1,774 women of childbearing age who survived within the 2,000 meter area, only 98 women were found to have been pregnant on Aug. 9, 1945. This group of irradiated mothers was further divided into (1) those mothers who had one or more "major" diagnostic signs of radiation injury, i. e., epilation, purpura and petechiae, and

資 料 の 収 集

A．患者の選択　この研究は1951年上半期に長崎で実施された。遺伝学的研究計画の妊娠記録から入手した資料に基づき，爆発時に妊娠可能年齢（本研究においては，17～50才とした）にあって長崎に居住していた婦人全部についてリストが作成された。爆撃当時，母親が妊娠していたかどうかを判定するためには訓練を受けた職員による家庭調査が行なわれた。受胎は最終の正常月経期の二週間後に起ったものとした。

原子爆弾の外傷性および放射線性影響は半径2,000m以内で最大であったから[52]爆発時に妊娠していたこの地区内の婦人を選んで被照射群を編成した。2,000

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oropharyngeal lesions and (2) those who had no evidence of radiation disease, or only "minor" signs. †

In selection of the control group, 4,000 to 5,000 meters was considered to be a distance sufficiently remote from the hypocenter so that only minimum effects of the explosion occurred.[52] In selection of the area from which the control group was drawn, due regard was given to the "fall-out" area where radioactive fission products from the bomb were said to have fallen.[53] Furthermore, in order to ensure maximum comparability, selection of the control group was based upon consideration of such factors as age distribution and similarity of population groups (nonrurural population). In the control area, 1,774 women of childbearing age were chosen at random, of whom 113 were found to have been pregnant on Aug. 9, 1945. Traumatic injuries in this group were limited to a few instances of minor glass cuts; no cases of flash burns or radiation sickness were encountered. Figure 1 indicates the age distribution of the control and irradiated groups of mothers.

B. Maternal History. Detailed pregnancy records and medical histories were obtained from the mothers in both groups. Clinical and experimental studies concerning the environmental factors affecting the development of fetuses were considered in obtaining the medical histories.[23-27]

The medical histories were taken by Japanese physicians who were familiar with the effects of the atomic bomb. Questionnaires were designed to consider the traumatic, thermal, and radiation effects with regard to time of onset, duration, and

mの地区内に生残った総数1,774名の妊娠可能年齢の婦人のうち1945年8月9日に妊娠していたものは98名に過ぎなかった。この放射線照射を受けた母親群はさらに(1)診断上放射線障害の「主要」症候，すなわち，脱毛，紫斑，点状出血，および口腔咽頭病変の1つ以上が認められた母親，および(2)放射線疾患を認めなかったもの，または「軽度」の症候† を認めたに過ぎないものに分類された。

対照群の選択に当っては，4,000m-5,000mの距離は，爆心から十分遠く離れていて，原子爆弾爆発の影響は極めて軽度であると考えられた[52]。対照群を抽出する地区の選択については，原子爆弾からの放射能性核分裂生成物が落下した[53]といわれている，いわゆる「降下物」地区には特別の注意を払った。さらに，最大限の比較を可能とするため，対照群の選択は，年齢分布および人口集団の類似性（都市部在住者）などの要因を考慮して行なった。対照地区においては妊娠可能年齢の婦人1,744名が無作意的に抽出されたが，そのうち1945年8月9日に妊娠していたものは113名であった。この群における外傷性障害は，軽度のガラス切傷を少数例に認めたにとどまり，熱傷または放射線疾患例には遭遇しなかった。図1は対照群および被照射群における母親の年齢分布を示す。

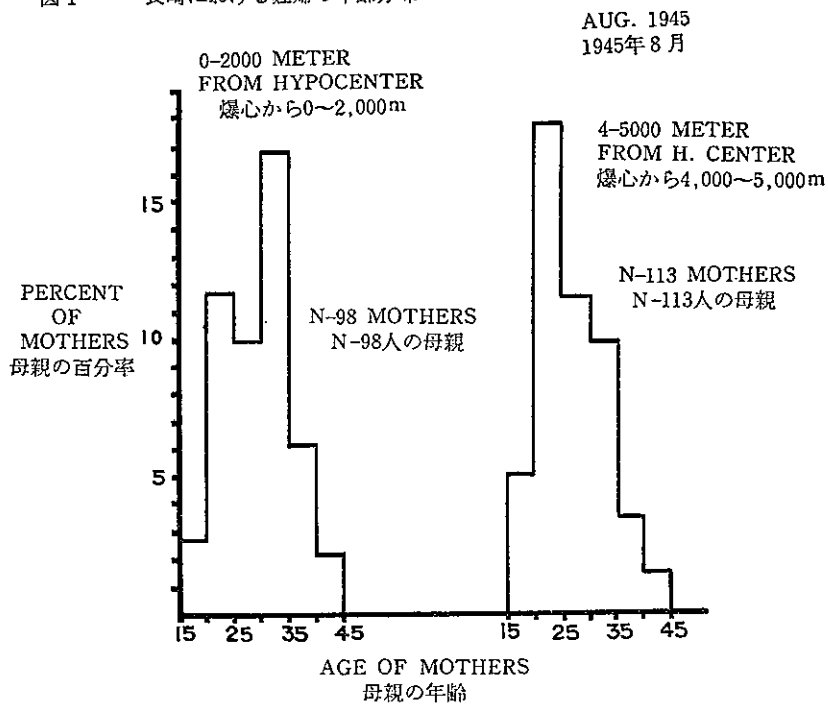
B．母性歴　詳細な妊娠記録および病歴を両群の母親から入手した。病歴[23-27]入手に当っては，胎児の発育に影響を及ぼす環境上の要因について，臨床的および実験的研究を実施することが考慮された。

原子爆弾の影響をよく知る日本人医師が病歴の記録に当った。質問書は，発病の時期，期間，および疾患の重さについて，外傷性，熱性，および放射線性影響が考察できるように作成された。母親との面接の際，

† Of the symptoms commonly encountered in the syndrome of radiation sickness, epilation, purpura and petechiae, and oropharyngeal lesions are generally considered to be the most reliable evidence of radiation injury and are designated in this study as "major" diagnostic signs. Malaise, vomiting, fever, and diarrhea, which are frequently manifestations of radiation sickness, may occur with many other illnesses. Considering the sanitary conditions which prevailed in the city immediately following the explosion, these latter symptoms are considered of "minor" importance in diagnosing radiation disease.

放射線疾患の症候群に普通見られる症状のうち，脱毛，紫斑および点状出血，並びに口腔咽頭病変は放射線障害の最も確かな証拠であると一般的に考えられており，本研究においてはこれを診断上の「主要」症候と定めた。放射線疾患にしばしば発現する倦怠，嘔吐，発熱および下痢は，他の多くの疾患においても見られる。まだ原子爆弾爆発直後における当該都市の衛生状態を考慮に入れれば，放射線疾患の診断を行なうに当り，これら後者の症状の重要性は「副次的」なものと考えられる。

Fig. 1.– Age distribution of pregnant women at Nagasaki.
図1　長崎における妊婦の年齢分布



severity. All of these histories were reviewed by American pediatricians at the time of interview with the mothers. Information on shielding was obtained, but sufficiently detailed data for qualitative or quantitative evaluation could not be gathered.

米人小児科医によってこれら病歴一切の検討が行なわれた。遮蔽に関する資料が入手されたが，定性または定量を行なうに足る詳細な資料は収集できなかった。

Serological tests for syphilis were performed whenever the history of findings indicated, i. e., if the pregnancy terminated abnormally, if the offspring was found to possess any defects, or if fetal, neonatal, or infant death had occurred.

所見記録を見て必要と認めた場合，たとえば妊娠の異常終結，産児の奇形または胎児，新生児，ないし乳幼児の死亡などの事実があった場合は，その都度血清梅毒検査が行なわれた。

C. Pregnancy Termination. The following definitions were used to define fetal, neonatal, and infant mortality.[28,29]

C．妊娠終結　胎児，新生児および乳幼児の死亡率[28,29]を示すに当っては，次の定義を用いた。

(1) Abortion. The spontaneous expulsion of a conceptus at the 20th week of gestation or earlier (no therapeutic abortions had been performed on any of the mothers)

(1) 流　産　妊娠第20週までの受胎産物の自然的娩出（いずれの母親にも治療的流産が実施されなかったもの）

(2) Stillbirth. Fetal death prior to the complete expulsion of the fetus from its mother after the 20th week of gestation

(2) 死　産　妊娠第20週後における完全娩出前の胎児の死亡

(3) Neonatal. Death death occurring within one month after the birth of the infant

(4) Infant death. Death occurring after the first month and during the first year of life

(5) Child morbidity. This term is reserved in this study for children who were found to be mentally retarded on clinical examination

If any pregnancy terminated abnormally or fetal or infantile death later ensued, details surrounding the incident were obtained. For all postnatal deaths a postmortem history was obtained.

Those children who had been fetuses in utero at the time of the bombing and were still residing in Nagasaki during the period of this investigation were seen at the Commission's clinic, where a medical history was taken and physical and ophthalmological examinations were performed.

The oldest child at the time of the examination was 5½ years, and the youngest was 4 years and 8 months. Anthropometric measurements were taken. Laboratory studies on every child included the following : urinalysis, total red and white cell count, hemoglobin determination, differential count, platelet count, sedimentation rate, and blood typing. Serological tests for syphilis were performed. Examination and cultures of the stools for ova and parasites were performed. X-rays were taken of the chest and of the hand for bone age.

Assessment of the child's developmental level was attempted following, in general, the motor, language, and social behavior levels outlined by Gesell for American children,[31] these standards having been considered applicable by the Japanese pediatricians. The mother's evaluation of the child compared to siblings and other children in the neighborhood was also considered in the assessment.

PRESENTATION OF DATA

I. Incidence of Radiation, Traumatic, and Thermal Injuries Among Radiated Mothers Within 2,000 Meters from the Hypocenter

(3) 新生児死亡　出生後1カ月以内における乳幼児の死亡

(4) 乳幼児死亡　最初の月を除いた出生後1年内における死亡

(5) 小児罹病率　この研究では，この言葉は臨床検査の際精薄児と認められた者について用いる。

妊娠が異常に終結した場合，または胎児ないし乳幼児の死亡がこれに続いて起った場合は，それに関する委細を調査した。出生後の死亡については，すべて剖検記録を入手した。

胎内被爆児であって，本調査期間中も依然長崎に居住していた小児については，ＡＢＣＣにおいて診察を行ない，病歴の記録，身体検査および眼科的検査を実施した。

検査時最年長児童は5½才で，最年少者は4才8カ月であった。人体計測が行なわれた。各児童の臨床検査では，尿，赤血球数および白血球数，血色素量，白血球分類像，血小板数，赤血球沈降速度，および血液型の検査が行なわれた。また血清梅毒検査が実施された。虫卵および寄生虫の有無を調べるため検査並びに便の培養検査が実施された。胸部X線検査，および骨格年齢を調べるために手のX線検査が行なわれた。

Gesellが米国児童について定めた運動，言語および社会行動規準に大体基づいて，小児の発育水準の評価を試みた。日本の小児科医によってこの規準が適用できると考えられたからである。評価に当っては，兄弟や近所の子供と比較した母親自身のその子供に対する評価も考慮に入れた。

資　料　の　提　示

I　爆心から2,000m以内で放射線照射を受けた母親における放射能性，外傷性および熱性障害の発現率

Table 1.– "Major" Radiation Signs in Mothers According to Distance from Hypocenter
表1　被爆距離別母親における「主要」放射能性症候

Distance from Hypocenter, M. 被爆距離 (m)	No. of Mothers 母親の数	Major Radiation Signs 主要放射能性症候		With Signs 有症候者 (%)
		Present ある	Not Present なし	
0– 500	1	1	…	100
501–1,000	8	3	5	37.5
1,001–1,500	34	19	15	55.9
1,501–2,000	55	7	48	12.7
Totals 計	98	30	68	

A. Radiation Injuries. Of the 98 mothers within 2,000 meters, 30 developed one or more "major" signs which have been generally considered as reliable evidence of radiation injury, i. e., epilation, oropharyngeal lesions, purpura, and petechiae. This group of mothers is referred to henceforth as mothers with "major" radiation signs. The remaining 68 mothers had either no signs or only "minor" signs. This group is referred to henceforth as mothers without "major" radiation signs.

Surveys of large numbers of exposed persons in Hiroshima and Nagasaki have shown that the development of radiation signs is a function of distance from the hypocenter.[32,52] Table 1 indicates the incidence of "major" radiation signs among the 98 irradiated mothers according to distances from the hypocenter. Four of the nine mothers within 1,000 meters had one or more "major" radiation signs. The highest incidence of radiation signs occurred in the group within 1,001 to 1,500 meters (56%), and the incidence dropped in the 1,501 to 2,000 meter group to 12.7%. Furthermore, the greatest number of women without radiation signs were in the 1,501 to 2,000 meter area. It can also be noted that in the group of 30 mothers with "major" signs, 23, or 77%, were within 1,500 meters of the hypocenter, whereas in the group of 68 mothers without "major" signs, only 20, or 29%, were in the same area. Within the 1,000 meter radius, where the mortality rate approached 99%,[52] the relatively low incidence of radiation

A．放射能性障害　被爆距離2,000m 以内の母親98名のうち，一般に放射線障害の確証と考えられる「主要」症候，すなわち脱毛，口腔咽頭病変，紫斑および点斑出血が1つ以上現われたものが30名あった。以下この母親群を「主要」放射線症候をもつ母親と呼ぶ。残余の68名の母親は，症候がないか，または「軽度」の症候が現われたに過ぎない。以下この群は「主要」症候をもたない母親と呼ぶ。

広島および長崎における多数の被爆者の調査は放射能性症候の発現が，爆心からの距離の関係であることを証明した[32,35]。表1は爆心からの距離別に放射線照射を受けた98名の母親の間の「主要」放射能性症候の発現率を示す。1,000m 以内では9名の母親のうち4名に1つまたはそれ以上の「主要」放射能性症候が認められた。1,001～1,500m群では放射能性症候は最高の発現率（56%）を示し，1,501～2,000m群ではそれは12.7%に下降した。更に放射能性症候のない婦人が最も多かったのは，1,501～2,000mの地域であった。「主要」症候をもつ30名の母親群のうち23名，すなわち77%は爆心から1,500m 以内にいたが，「主要」症候のない68名の母親群では，わずかに20名すなわち29%が同地区にいたに過ぎない。死亡率が99%[52]に近かった半径1,000m 以内では，少数の生存者における放射能性症候の発現率は比較的に低かったが，これは恐らく効果的な遮蔽によるものであろう。

signs in the few survivors can probably be accounted for by effective shielding.

B. Traumatic Injuries. Trauma was reported in two-thirds of the 30 mothers with "major" radiation signs (Table 2). Injuries to the extremities occurred in 11 mothers ; 2 of these pregnancies terminated in fetal deaths. Injuries to the chest or abdomen occurred in nine mothers, with three fetal deaths.

Among the 68 mothers who did not show "major" radiation signs, 29.4% had injuries. No fetal deaths occurred in this group, but a comparative evaluation of the severity of the wounds was not possible.

C. Thermal Injuries. Within 2,000 meters, only 4 of the 98 mothers gave a history of severe flash burns. One mother at 1,900 meters received extensive flash burns, and these required eight months to heal. The infant born to this mother died at 2 months of age of "congenital weakness."

B．外傷性障害　「主要」放射能性症候（表２）をもつ30名の母親の⅔に外傷が報告された。四肢の障害は11名の母親が受けているが，そのうちの２名は胎児が死亡した。胸部または腹部の障害は９名の母親に認められ，この場合胎児死亡例は３であった。

「主要」放射能性症候を示さなかった68名の母親のうち，29.4%が負傷していた。この群では胎児の死亡は起らなかったが，負傷の程度は比較できなかった。

C．熱性障害　2,000m 以内では，98名の母親のうち４名に重篤な熱傷歴があったに過ぎない。1,900m で被爆した１名の母親は広範囲に及ぶ熱傷を受け，その傷が治癒するのに８カ月を要した。この母親に生まれた乳児は，生後２カ月で「先天性虚弱」で死亡して

Table 2.– Relation of Maternal Trauma to Fetal Death
表２　母親の外傷と胎児の死亡との関係

Group of Mothers, 0–2,000 M. 0〜2,000m　母親群	No. of Mothers 母親の数	Trauma to Extremity 四肢の外傷	No. of Fetal Deaths 胎児死亡数	Trauma to Chest or Abdomen 胸部又は腹部の外傷	No. of Fetal Deaths 胎児死亡数	Trauma 外傷 (%)	Fetal Deaths 胎児死亡 (%)
"Major" radiation signs..... 「主要」放射能性症候のあるもの	30	11	2	9	3	66.7	16.7
No "major" radiation signs..... 「主要」放射能性症候のないもの	68	11	0	9	0	29.4	0

Three other women had less extensive flash burns of the extremities. Another received fire burns of one extremity at 700 meters. The low incidence of burns among these mothers was undoubtedly a factor in determining their survival, since burns incurred within 2,000 meters were usually severe enough so that when combined with radiation injuries, death ensued.[52]

いる。３名の他の婦人は，四肢に熱傷を受けたが，その範囲は上例よりもせまかった。更に１名が700mの距離で一肢に火傷を受けている。これらの母親達に熱傷が少なかったことは，疑いもなく彼女らの生残りを決定する要因となっている。その理由は，2,000m以内で受けた熱傷は，大抵は重傷で，それが放射線障害と合併した場合は結局死亡しているからである[52]。

Table 3.– Fetal Mortality Among Irradiated and Control Groups

表３　被照射群および対照群における胎児の死亡

Group　群	No. of Conceptions 受胎数	No. of Abortions 流産数	No. of Stillbirths 死産数	Fetal Mortality 胎児死亡 (%)
0–2,000 M., "major" radiation signs..... 0～2,000m「主要」放射能性症候のあるもの	30	3	4	23.3
0–2,000 M., no "major" radiation signs..... 0～2,000m「主要」放射能性症候のないもの	68	1	2	4.4
4,000–5,000 M., controls..... 4,000～5,000m　対照者	113	2	1	2.7

Ⅱ. Pregnancy Terminations Among Irradiated and Control Groups with Reference to Fetal, Neonatal, and Infant Mortality and Child Morbidity Rates.

A. Fetal Mortality (Table 3). 1. Irradiated Women Within 2,000 Meters and with "Major" Signs of Radiation Disease, i. e., Epilation, Purpura, and Petechiae, or Oropharyngeal Lesions: Of the 30 mothers who were within 2,000 meters and who developed major radiation signs, 3 aborted spontaneously, 4 delivered stillborn fetuses, and 23 gave birth to living infants. The three abortions all occurred at the height of the radiation illness between the fourth and fifth weeks following the explosion of the bomb. Petechiae, purpura, or tendency to bleed from the mucous membranes was present in all three mothers. One mother incurred moderate first and second-degree flash burns. Traumatic injuries to the extremities or chest and abdomen occurred in two of these three mothers, but its importance is difficult to evaluate, since the abortions did not occur until four to five weeks after the trauma.

Three of the four stillbirths occurred within the two weeks immediately following the explosion. The deliveries occurred before the development of the radiation illness which, however, when it did develop was moderately severe. Significant trauma to the abdomen and other parts of the body was said to have occurred in two of these three mothers. The fourth dead fetus was born nearly half a year after the explosion to a mother who

Ⅱ　胎児，新生児，乳幼児死亡率および小児罹病率から見た被照射群および対照群における妊娠の終結

A．胎児死亡率（表３）

1．2,000m 以内で放射線照射を受け，放射能性疾患，すなわち脱毛，紫斑，および点状出血，または口腔咽頭病変の「主要」症候のあった婦人。2,000m 以内で被爆して主要放射能性症候のあった30名の母親のうち，３名が自然流産し，４名が死産し，23名が出産した。３例の流産はいずれも原子爆弾爆発後の第４週から第５週の間，放射能性疾患が最高潮に達した際に起った。３名の母親にはいずれも点状出血，紫斑，または粘膜出血の傾向があった。１名の母親は第１度および第２度の熱傷を中等度に受けた。これら３名の母親のうち２名は，四肢または胸部および腹部に外傷を受けているが，流産は受傷後４～５週間を経て起っているから，その外傷の重要度の判定は困難である。

４例の死産のうち３例は爆発直後の２週間内に起っている。分娩は放射性疾患が現われないうちに行なわれているが，この放射能性疾患は中等度に重篤であった。これら３名の母親のうち２名は腹部その他に有意の外傷を受けたという。第４の死産は，同じく外傷を受け，さらに妊娠中に全身性浮腫を伴う腎臓疾患を生じた母親に，原爆後ほとんど半年を経過して起ってい

also experienced trauma but, in addition, developed renal disease with generalized edema during the pregnancy. This mother again developed the same clinical condition in two subsequent pregnancies which terminated in two normal infants. In 1951 she was found to have developed diabetes.

2. Irradiated Women Within 2,000 Meters and Without "Major" Signs of Radiation Disease: Of the 68 mothers who were within 2,000 meters and did not develop "major" radiation signs, there was 1 abortion and 2 stillbirths; the remaining 65 infants were live-born. No definite cause for the abortion could be found. One stillbirth was the result of a difficult manual delivery from a transverse position. The other stillbirth was a macerated fetus, born two months after the explosion. The mother was about 8 meters within the entrance to an air raid shelter, 1,150 meters from the hypocenter, and did not develop "major" signs of radiation.

3. Control Women (4,000 to 5,000 Meters from Hypocenter): Of 113 pregnancies in the control group, there were 2 abortions, 1 stillbirth, and 110 living infants. The cause of the abortion in one instance was unknown. In the second instance, it

る。この母親にはその後の2回の妊娠においても同様の臨床的症状が現われたが，この際は，それぞれ正常児を分娩している。1951年には糖尿病の発病を見た。

2. 2,000m 以内で放射線照射を受け「主要」放射能性疾患の症候のなかった婦人。2,000m 以内で被爆し「主要」放射能性症候を生じなかった68名の母親のうち，流産1例および死産2例があり残余の65名の乳幼児は出産児であった。流産の原因は明らかでない。死産1例は，横位による困難な用手分娩の結果であった。他の死産は，爆発後2カ月して生まれた浸軟児であった。その母親は爆心から1,150m の防空壕内入口から約8mの所におり「主要」放射能性症候はなかった。

3. 対照婦人（爆心から4,000～5,000m）。対照群における113例の妊娠のうち，流産2例，死産1例，出生した乳幼児は110名であった。流産1例は原因不明であった。流産第2例では，分娩後5日目に「滲出

Table 4.– Fetal, Neonatal, and Infant Mortality and Child Morbidity Rates According to Stage of Gestation Among Irradiated Groups (0–2,000 Meters)

表4　被照射群（0～2,000m）における妊娠段階別胎児，新生児および乳幼児死亡率，並びに小児罹病率

Trimester of Pregnancy 妊娠期	"Major" Radiation Signs 「主要」放射能性症候のあるもの				No "Major" Radiation Signs 「主要」放射能性症候のないもの			
	No. Conceptions 受胎数	Fetal Mortality 胎児死亡率 (%)	Neonatal and Infant Mortality 新生児および乳幼児死亡率 (%)	Child Morbidity 小児罹病率 (%)	No. Conceptions 受胎数	Fetal Mortality 胎児死亡率 (%)	Neonatal and Infant Mortality 新生児および乳幼児死亡率 (%)	Child Morbidity 小児罹病率 (%)
Ⅰ	10	30	0	10	12	8.3	16.6	8.3
Ⅱ	10	30	20	20	27	3.7	…	…
Ⅲ	10	10	40	10	29	3.4	3.4	…
Totals 計	30				68			

may have been due to an infectious process in the mother, inasmuch as an "exudative pleurisy" was diagnosed on the fifth postpartum day. A difficult delivery from a foot presentation was thought to have been the cause of the stillbirth, since fetal movements had been felt on the day prior to delivery.

4. Summary of Fetal Mortality in Irradiated and Control Groups: The fetal mortality among the irradiated and control groups is indicated in Table 3. Among the group with "major" radiation signs, there was a 23.3% fetal loss. All of the seven fetal deaths occurred among 19 mothers who were in the 1,001 to 1,500-meter areas (Table 1). Fetal mortality in the irradiated group without "major" signs and in the control group was much lower, 4.4% and 2.7%, respectively.

Fetal loss according to the stage of gestation at the time of the explosion is shown in Table 4. It will be noted that in the irradiated group with "major" signs the fetal losses are greater in each trimester, 30%, 30%, and 10%, as compared to the losses in the mothers without "major" radiation signs, where the losses were 8.3%, 3.7%, and 3.4%, respectively. Data on the control group of mothers have been omitted, although the mortality rates were considerably lower than for the irradiated groups.

B. Neonatal and Infant Mortality (Table 5).

1. Mothers Within 2,000 Meters and with "Major" Signs of Radiation: Of 30 conceptions in this group, 7 terminated in fetal deaths, and 23 infants were live-born. Among these there were three neonatal and three infant deaths. The following causes were given for the neonatal deaths: prematurity, "congenital weakness" with failure to nurse adequately, and melena associated with hematemesis. Two of the neonatal deaths occurred in infants born in August, 1945, shortly after the explosion.

The three infant deaths which occurred in the second and third months of life were due to exfoliative dermatitis with epilation, omphalitis with

性胸膜炎」の診断を受けているから母親の感染が，その原因であったかも知れない。死産は分娩の前日に胎児の運動が認められたから，足位による分娩困難が原因であったと考えられる。

4. 被照射群および対照群における胎児死亡率総括。被照射群および対照群における胎児の死亡率は表3に示す。「主要」放射能性症状をもつ群にあっては胎児の死亡は23.3%に達した。7例の胎児死亡は，すべて1,001～1,500mの地区内（表1）にあった19名の母親に起った。「主要」症候のない被照射群および対照群の示す胎児死亡率は，はるかに低率で，それぞれ4.4%および2.7%であった。

爆発時における妊娠段階別胎児死亡率は表に示す。「主要」症候のない母親においては各妊娠3ヵ月期における胎児死亡率が，8.3%，3.7%および3.4%であったのに対し，「主要」症候をもつ被照射群にあっては胎児死亡率は，それぞれ30%，30%および10%で，より高率である。対照群の母親に関する資料の提示は省略したが，被照射群に比べてその死亡率は相当に低率であった。

B. 新生児および乳幼児死亡率（表5）

1. 爆心地から2,000m以内で被爆し「主要」放射能性症候をもつ母親。この群における受胎30例中7例は胎児のうちに死亡し，23名が出産した。このうち3例の新生児死亡および3例の乳幼児死亡があった。新生児死亡については次の理由，すなわち，早産，十分な哺乳ができない「先天性虚弱」および吐血症に関連したメレナが原因としてあげられた。新生児死亡2例は，1945年8月に生まれた乳幼児で，爆発後間もなく死んでいる。

生後2ヵ月および3ヵ月後における乳幼児死亡3例は，脱毛を伴う剝脱性皮膚炎，敗血症を伴う臍炎および「先天性虚弱」に起因していた。剝脱性皮膚炎の認

sepsis, and "congenital weakness." The mother of the infant with exfoliative dermatitis developed severe radiation illness which continued for a month after the birth of the infant, in early September. The mother's serology was negative in March, 1951. The skin lesions in the infant developed toward the end of the first month of life, beginning with an erythema which progressed into an exfoliative dermatitis. Epilation is also said to have occurred in this infant.

められた乳児の母親には，9月早々重篤な放射能性疾患が現われ，これは出産後も1カ月間持続した。1951年3月におけるその母親の血清梅毒反応は陰性であった。乳児の皮膚病変は生後1カ月目の終り頃に起り，紅斑をもって始まり，剥脱性皮膚炎に進行した。この乳児には脱毛も起ったとのことである。

Table 5.– Neonatal and Infant Mortality Among Irradiated and Control Groups
表5　被照射群および対照群における新生児および乳幼児死亡率

Group　群	Mothers* 母　親	Neonatal Deaths 新生児死亡	Infant Deaths 乳幼児死亡	Mortality, 死亡率 (%)
0–2,000 M., "major" radiation signs..... 0～2,000m「主要」放射能性症候のあるもの	23	3	3	26.1
0–2,000 M., no "major" radiation signs..... 0～2,000m「主要」放射能性症候のないもの	65	3	0	4.6
4,000–5,000 M., controls..... 4,000～5,000m　対照者	110	1	3	3.6

* Mothers of living infants: stillbirths and abortions excluded.
生産児の母親，死産および流産は除外した。

The mother of the infant who died of "congenital weakness" was in her fifth month of pregnancy at the time of the bombing and received extensive flash burns of the face, chest, and extremities which required eight months to heal.

「先天性虚弱」で死亡した乳児の母親は，原爆投下の際は妊娠5カ月であったが，顔面，胸部および四肢に広範囲の熱傷を受け，これが治癒するのに8カ月を要した。

2. Mothers Within 2,000 Meters and Without "Major" Signs of Radiation Disease: There were 3 fetal deaths among the 68 pregnancies in this group. Among the 65 live-born infants, there were 3 neonatal deaths. A premature separation of the placenta resulted in the birth of one infant in the 36th week of gestation who survived for only 36 hours. The second death occurred in an infant who developed a generalized maculopapular morbilliform rash which persisted until death. Serological tests for syphilis performed on the mother were strongly positive in March, 1951. The third infant died after one week of life from undetermined causes.

2．爆心地から2,000m以内で被爆し「主要」放射能性症候のない母親。この群では，68例の妊娠のうち3例の胎児死亡があった。65例の出産児のうち，新生児死亡が3例あった。1名の乳幼児は妊娠第36週目に胎盤の早期剥離によって出生したが，わずか36時間生きただけであった。第2の死亡例では全身性斑状丘疹状皮疹が生じ，死ぬまで持続した。その母親に対し実施した血清梅毒反応は，1951年3月には強陽性であった。第3の乳幼児は原因不明で生後1週間目に死亡した。

3. Control Group (4,000 to 5,000 Meters from Hypocenter): Among 113 pregnancies in the control group there were 3 fetal deaths, and in the remaining 110 live-born infants there was one neonatal death and three infant deaths. The neonatal death occurred on the 20th day in an infant who developed a skin rash and seemed to "waste away." The mother's serological tests for syphilis were strongly positive. Respiratory infection caused the deaths of three infants.

4. Summary of Neonatal and Infant Mortality in the Irradiated and Control Groups: Neonatal and infant losses for the three groups of mothers are summarized in Table 5. There is a high neonatal and infant mortality in the group of mothers with "major" signs of radiation disease (26.1%), as compared to the group without "major" signs (4.6%) and the controls (3.6%).

A comparison of neonatal and infant loss according to stage of gestation is shown in Table 4. It will be noted that for the group with "major" radiation signs the losses were 0%, 20%, and 40% for the three trimesters, respectively, and for the group without "major" signs, 16.6%, 0%, and 3.4%, respectively.

C. Child Morbidity Among Irradiated and Control Groups (Table 6).

1. Mothers Within 2,000 Meters with "Major" Signs of Radiation Disease: Of 30 conceptions in this group, there were 7 fetal deaths and 6 neonatal and infant deaths. Of the 17 children who survived infancy, one child died of "dysentery" at 2½ years of age. The following observations were made on the 16 remaining children, who were between the ages of 4-8/12 and 5-6/12 years of age at the time of clinical examinations: 12 were mentally normal, while 4 were found to have varying degrees of mental retardation. All four were noted to be relatively retarded in their physical development. The mothers of these children had been 850 to 1,150 meters from the hypocenter.

Moderate to severe impairment of speech was noted in these children. Two had never talked by the age of 5 years; speech was incoherent in

3. 対照群（爆心から4,000～5,000m）。対照群においては113例の妊娠のうち，3例の胎児死亡があり，残余の110名の出産児においては，1例の新生児死亡および3例の乳幼児死亡があった。新生児死亡は20日目に起ったもので，皮疹を生じ「徐々に衰弱」したようであった。その母親の血清梅毒反応は強陽性であった。3名の乳幼児の死亡は呼吸器感染が原因であった。

4. 被照射群および対照群における新生児および乳幼児死亡率総括。3群の母親における新生児および乳幼児の死亡を表5に総括して示す。「主要」放射能性症候のある母親群（26.1%）においては「主要」放射能性症候のない母親群（4.6%）および対照群（3.6%）と比較して，新生児および乳幼児の死亡率がいずれも高率である。

妊娠段階別，新生児および乳幼児死亡の比較は表4に示す。「主要」放射能性症候をもつ群では妊娠3期に対応する死亡率は，それぞれ0%，20%および40%であり「主要」放射能性症候のない群では，それぞれ16.6%，0%および3.4%であった。

C．被照射群および対照群における小児罹病率（表6）

1. 2,000m以内で被爆し「主要」放射能性疾患のある母親。この群においては，30例の受胎のうち，胎児死亡が7例，新生児死亡および乳幼児死亡が6例あった。乳児期を生残った17名の小児のうち，1名の小児は，2½才の時「赤痢」で死亡した。臨床検査時に4才8カ月から5才6カ月までの間にあった残りの16名の小児について行なわれた観察の結果は次の通りである。12名は知能の発育が正常であったが，4名にはそれぞれ程度を異にする知能の遅れを認めた。この4名はいずれも身体の発育も比較的に遅れていた。これら小児の母親は爆心から850m～1,150mの間で被爆している。

これらの小児においては中等度から強度に至る言語障害が認められた。2名は5才まで口がきけなかった。他の1名は話す言葉にまとまりがなかった。第4

Table 6.– Child Morbidity Among Irradiated and Control Groups

表6　被照射群および対照群における小児罹病率

Group　群	Mothers* 母　親	Mental Retardation in Child 精薄児	Alive and Normal Child after 1 yr. of Life 生後1年目における健常児	Loss, 死　亡 (%)
0–2,000 M., "major" radiation signs..... 0～2,000m「主要」放射能性症候のあるもの	16	4	12 +	25.0
0–2,000 M., no "major" radiations signs..... 0～2,000m「主要」放射能性症候のないもの	60	1	59++	1.6
4,000–5,000 M., controls..... 4,000～5,000m　対照者	106	0	106 §	0

* Includes mothers whose children were alive at time of examination.
検査時に生存していた小児の母親を含む

\+ Nystagmus, corneal opacity, and pupillary membrane in one child.
1名の小児に眼振，角膜混濁および瞳孔膜あり

++ Urinary incontinence in one child.
1名の小児に尿失禁あり

§ Unilateral cataract in one child.
1名の小児に片眼白内障あり

another ; and in the fourth, speech was intelligible only to the immediate family.

At the time of the bombing, three of these mothers, including the mother of one microcephalic idiot, were in the first half of pregnancy, and the fourth was in the 36th week of gestation, the offspring of whom was a spastic child. In addition, one child, mentally normal, was found to have a corneal opacity associated with a pupillary membrane and nystagmus ; the mother of this child also had nystagmus.

2. Mothers Within 2,000 Meters and Without "Major" Radiation Signs: Of 68 conceptions in this group, there were 3 fetal deaths and 3 neonatal deaths. Of the remaining 62 infants who survived the period of infancy, 2 died of respiratory disease at the age of 2 and 3 years, respectively. There was one mentally retarded and spastic child, whose performance level at the age of 5 years was that of a 2– to 3– year–old. The mother of this child had been pinned under the fallen timbers of her home. She was able to extricate herself from the debris, and no visible injuries of the abdomen were recalled. However, she sustained contusions of her head and shoulders. Another child had urinary incontinence, and intravenous pyelogram studies of the genitourinary tract revealed a

の小児の言葉は近親者でなければ理解できなかった。

爆発時には1名の小頭白痴児の母親を含むこれら母親のうち3名は妊娠前半期にあり，第4の母親は，妊娠第36週にあって，生まれた子は痙攣児であった。なお正常な知能の発育を示した1名の小児に，瞳孔膜および眼振，並びに関連性の角膜混濁が認められたが，この小児の母親にも眼振があった。

2．2,000m以内で被爆し「主要」放射能性症候のない母親。この群においては，68例の受胎のうち3例の胎児死亡および3例の新生児死亡があった。乳児期を生残った残余の62名の乳幼児のうち2名は2才および3才でそれぞれ呼吸器疾患で死亡した。精薄痙攣児が1名あって，5才の時の知能水準は，2～3才の小児のそれに相当した。この小児の母親は自宅で倒壊家屋の木材の下敷きになったが，倒壊物の下から脱出することができた。腹部に外傷を受けた記憶はない。しかし，頭部および肩甲部に打撲傷を受けた。もう1人の小児には尿失禁があり，静注法腎盂X線検査による性尿路検査において，膀胱に対する圧力欠如を認めたが，その原因は明らかでない。母親の血清梅毒反応は陽性であった。

pressure defect against the bladder ; the cause was not determined. The mother's serological test for syphilis was positive.

3. Control Group (4,000 to 5,000 Meters) : In the control group there were 113 conceptions, of which 3 terminated in fetal deaths and 4 as neonatal or infant deaths The remaining 106 children were living and were examined in clinic ; all were found to be mentally normal.

The only abnormal finding in children of the control group was a unilateral cataract in one child, the etiology of which was not determined.

4. Summary of Child Morbidity and Anthropometric Measurements for the Irradiated and Control Groups : The child morbidity rate in the irradiated and control groups is shown in Table 6. The incidence of children with mental retardation was 25.0% (four cases) in the irradiated mothers with "major" signs. This is considerably higher than in the irradiated group without "major" signs and the control group, where the rates were 1.6% (one case) and 0%, respectively.

Child morbidity according to the stage of gestation was higher in the irradiated group with "major" signs, 10%, 20%, and 10% for each trimester, as compared to the irradiated groups without "major" signs, where the incidence was 8.3%, 0%, and 0% for the first, second, and third trimesters, respectively (Table 4).

3. 対照群 (4,000～5,000m)。対照群においては113例の受胎があった。そのうち3例に胎児死亡があり，4例に新生児ないし，乳幼児死亡があった。残余の106名の児童は生存していて，診察室で検査を受けたが，いずれも知能の発育は正常であった。

対照群の小児における唯一の異常所見は，1名の小児の一側性白内障であって，病因は明らかでない。

4. 被照射群並びに対照群における小児罹病率および人体計測値の総括。被照射群および対照群における小児罹病率は表6に示す。精薄児の発現率は「主要」症候をもつ被照射群の母親においては25.0%（4例）であった。これは「主要」症候のない被照射群および対照群における発現率がそれぞれ1.6%（1例）および0%であるのに比較して相当に高率である。

妊娠段階別，小児罹病率は，「主要」症候のない被照射群では，妊娠第1，第2および第3期に対応する発現率がそれぞれ8.3%，0%および0%であったのに比べて，「主要」症候のある被照射群では，それぞれ10%，20%および10%でより高率であった。(表4)

Table 7.- Mean Height, Weight, and Head Circumference of all Children Examined
表7　全被検児の平均身長，体重および頭囲

Group　群	No. of Children 小児の数	Mean Height ± S. D., Cm. 平均身長 ±標準偏差 (cm)	Mean Weight, kg. 平均 体　重 (kg)	Mean Head Circumference ± S. D., Cm. 平均頭囲 ±標準偏差 (cm)
0-2,000 M., "major" radiation signs..... 0～2,000m「主要」放射能性症候のあるもの	16	98.6 ± 3.29	15.0	47.18 ± 2.08
0-2,000 M., no "major" radiation signs..... 0～2,000m「主要」放射能性症候のないもの	57 *	102.6 ± 4.28	16.8	49.50 ± 1.42
4,000-5,000 M., controls..... 4,000～5,000m　対照者	96 +	101.56 ± 4.64		49.08 ± 1.15

* Three of the 60 children did not receive anthropometric measurements.
小児60名のうち3名は人体計測を受けなかった。

\+ Ten of the 106 children did not receive anthropometric measurements.
小児106名のうち10名は人体計測を受けなかった。

The mean height, weight, and head circumference of the children examined in clinic* is shown in Table 7. The mean height of the 16 children born to mothers with "major" radiation signs was 98.6 cm. The observed difference in mean height between the control and "major" radiation signs group is 2.9 cm., and the probability of observed difference being due to chance is less than 0.01.

診察室で調べた小児の平均身長，体重および頭囲は表7に示す。「主要」放射能性症候のある母親に生まれた16名の小児の平均身長は98.6*cm*であった。対照群と「主要」放射能性症候群との間の観察差は2.9*cm*であって偶然に起因する観察差確率は0.01以下である。

The mean weight in the groups was as follows: 15 kg. in the children whose mothers had "major" radiation signs and 16.8 kg. in the children whose mothers had no "major" signs; the ratio of height to weight in each group, including the control group, remained unchanged.

この群の平均体重は次のとおりであった。「主要」放射能性症候のあった母親をもつ小児では15*kg*，「主要」症候のなかった母親をもつ小児では16.8*kg*で，対照群を含めた各群における身長対体重の比率は不変であった。

In Figure 2, the height and weight measurements are indicated for children born to mothers with and without "major" signs of radiation. It can be seen that children born to mothers with "major" signs represented by open circles on the figure, are definitely retarded in their growth and development. Three of the five lowest circles represent children who were mentally retarded.

図2は「主要」放射能性症候のある母親およびない母親に生まれた小児の身長および体重計測値を示す。「主要」症候をもつ母親に生まれた小児は，塗り潰してない円によって示したが，その発育および栄養は明らかに遅れている。最下位の5つの円のうち3つは精薄児を示す。

The mean head circumference of children born to mothers with "major" signs was 47.18 cm. and for children of mothers without "major" signs, 49.50 cm. The mean circumference in the control group of children was 49.03 cm. The observed difference between the group with "major" signs and the control group was 1.85 cm., and the probability of the observed difference being due to chance is less than 0.01.

「主要」症候をもつ母親に生まれた小児の平均頭囲は47.18*cm*で，「主要」症候のない母親に生まれた小児のそれは49.50*cm*であった。対照群小児の平均頭囲は49.03*cm*であった。「主要」症候群と対照群との観察差は1.85*cm*で，偶然に起因する観察差確率は0.01以下である。

The head circumference of the three groups is shown graphically in Figure 3. The head circumferences of the four children with mental retardation were 41.7 cm., 44.3 cm., 46.5 cm., and 46.7 cm., respectively; accounting for the four smallest measurements in the group of children whose mothers had "major" radiation signs.

3群の頭位は，図3にグラフをもって示した。精薄児4名の頭位は，それぞれ41.7*cm*，44.3*cm*，46.5*cm*，および46.7*cm*であって，これら4例はすなわち「主要」放射能性症候をもつ母親に生まれた小児群における最小計測値を示す。

COMMENT AND INTERPRETATION

考察並びに解説

As an aid in evaluating this study, a brief review is presented of some of the pertinent literature concerning the effect of radiation on

本研究を評価する参考として，動物および人間の胎児に対する放射線の影響並びに組織に対する放射線の

Fig. 2.- Height and weight of children in utero within 2000 meters of atomic bomb blast at Nagasaki.

図2　長崎における2,000m以内の胎内被爆児の身長および体重

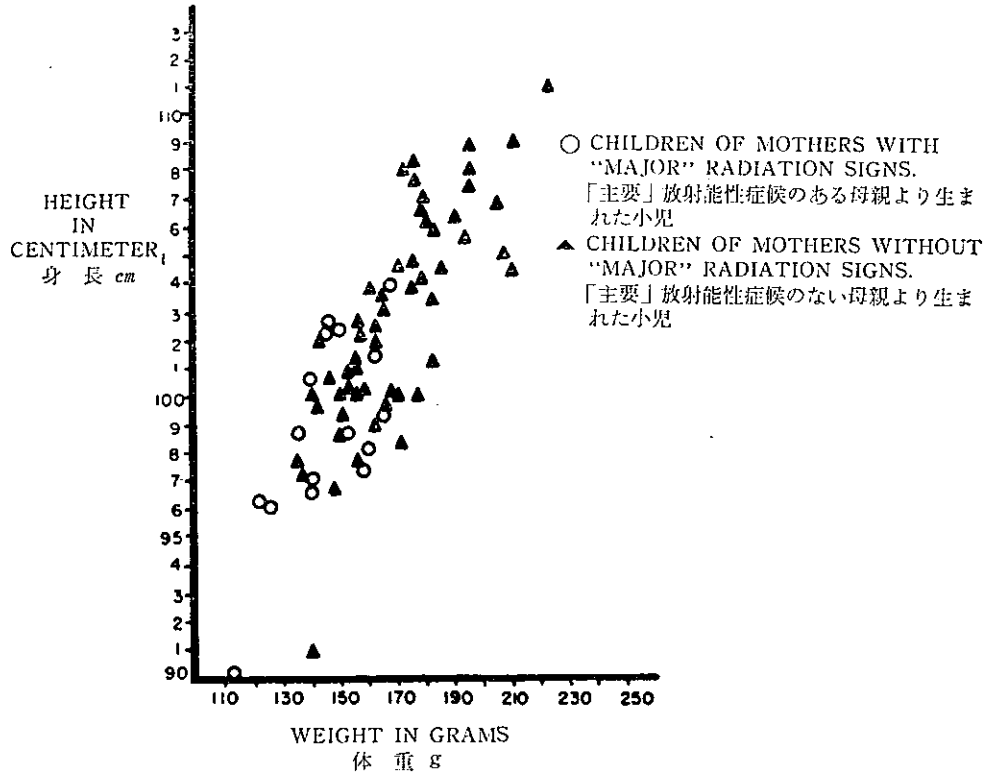
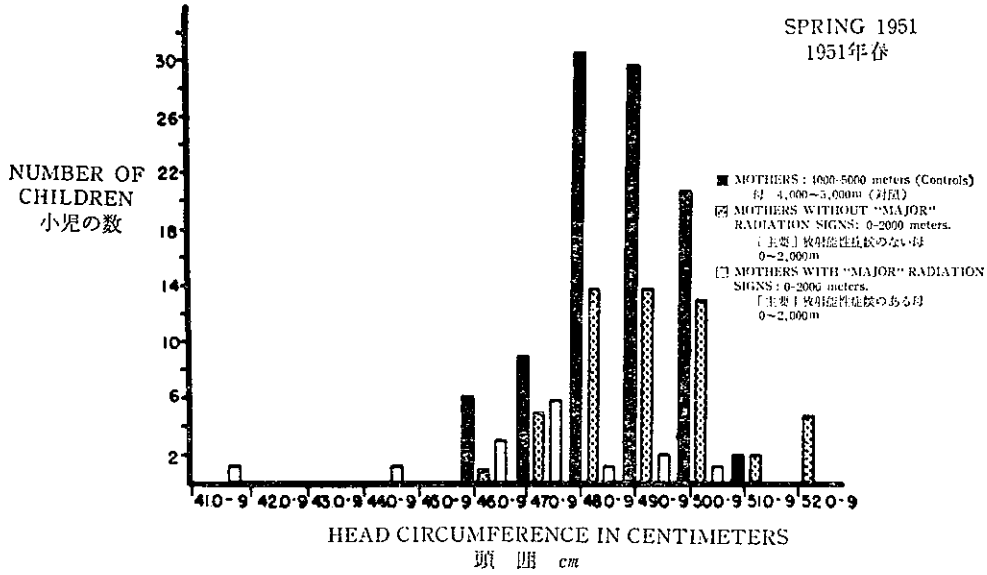


Fig. 3.- Head circumference of children in utero at Nagasaki.

図3　長崎における胎内被爆児の頭囲



animals and human fetuses and the biological effect of radiation on tissues. Experimental, studies on irradiated mammals, particularly rodents, have revealed reduced fetal and postnatal viability, as well as skeletal and visceral malformations.[1-16] Organs at critical stages of development have been shown to be highly susceptible to a relatively low radiation dosage, whereas with high dosages, abnormalities could be produced at any stage of development.[4,7-8,10] In addition, viability, the degree of retardation of growth, and the type of abnormality were determined by the dosage and the stage of fetal development,[2] Wilson noted, in addition to skeletal and visceral malformations in irradiated mice fetuses, structural abnormalities in the liver manifested by absent or reduced hematopoietic activities and assocaited with a high mortality rate.[13]

The effect of radiation on the brain merits particular attention. The radiosensitivity of the neuroblasts in the embryo nervous system is in marked contrast to the radioresistance of the adult nervous system. Rat embryos exposed to radiation on the ninth day of gestation developed tumor-like growths in the brain, which microscopically consisted of closely packed masses of cells of the developing neural tube.[14] With larger dosages, 200 to 600 r, Hicks produced acute necrosis of the rapidly growing parts of the brain, spinal cord, and retina in rat and mice fetuses.[5,6] Radiation damage was most severe in the area in which rapid growth was occurring. For example, at birth or in the immediate postnatal periods the outer cerebellar cortex, where growth is most rapid, was damaged, and the spinal cord, where the rate of cell multiplication has decreased, was spared. There is, however, evidence that growth rate alone is not the only factor in etermining cellular radiosensitivity. Enzyme inhibitors, especially those that simulate radiation reactions by interfering with sulfhydryl enzymes, have been used to produce brain malformations in rat and mice fetuses.[6]

Little attention is given in the literature to the exact cause of the postnatal death of offspring of irradiated animals. The associated findings of

生物学的影響を取扱った適当な参考文献若干について簡単な検討を試みたい。

放射線照射を受けた哺乳動物，特に囓歯類動物について行なわれた実験的研究においては，骨格および内臓の奇形とともに，胎児期および出生後における生育力の減弱が認められた[1-16]。最も盛んな発育段階にある臓器は，比較的に低い放射線量に対しても非常に敏感であることが知られているが，高い線量の場合は如何なる発育段階にあっても，異常が起り得るであろう[4,7-8,10]。更に生育力，成長遅延の程度，および異常の種類も，線量および胎児の発育段階[2]によって決定される。Wilson は放射線照射を行なったマウスの胎児に，骨格および内臓の奇形のほかに肝臓の構造上の異常を認めたが，これは造血活動の欠如または減退となって現われており，ひいては高死亡率[13]につながっていた。

頭脳に対する放射線の影響は，特に注目に価する。胎児の神経系における神経芽細胞の放射線感受性は，成人神経系の放射線抵抗に対して著しい対照を成す。妊娠第9日目に放射線照射を行なったラットの胎児の脳に腫瘍様の新生物が発生したが，これは顕微鏡的には発育中の神経管細胞がぎっしり詰まった塊りからなっていた[14]。Hicks はさらに線量を増して200～600 r の照射を行ない，ラットおよびマウスの胎児の脳，脊髄，および網膜の急速な成長が行なわれている部分に急性壊疽を起させた[5,6]。放射線傷害は，この急速な成長が行なわれていた部位で最も強かった。たとえば出生時または出生直後にあっては，生長が最も急速な小脳外側の皮質が障害を受け，細胞増加率が減少していた脊髄はこれを免がれた。しかし，発育率だけが細胞の放射線感受性を判定する唯一の要因ではない証左がある。酵素抑制物質特にスルフヒドリル基酵素に干渉することによって，放射線反応に似た反応を起す酵素抑制物質は，ラットおよびマウスの胎児に脳の奇形を起させるのに使用されてきた[6]。

参考文献においては，放射線照射を受けた動物の子の出生後における死亡の正確な原因に対してはほとんど注意が向けられていない。貧血，下痢，出血傾向，

anemia, diarrhea, hemorrhagic tendencies, weight loss, and abnormal nervous phenomena seem to indicate that death was due to direct radiation damage of vital tissues.[2]

体重減少および異常神経現象などの関連性所見の示すところによれば，その死は生体組織が直接放射線障害を受けたことによるものであろう[2]。

Studies of pregnancy terminations in women who have had pelvic radiation have yielded valuable information concerning the effect of radiation on the human fetus.[18-22] Mayer and co-workers reported that a single dose of 360 r to the center of the uterus caused a therapeutic abortion in the majority of cases.[21] Murphy and co-workers[17-19,22] noted that pelvic radiation of pregnant women resulted in a high incidence, 37% (28 of the 75 children) of mental or physical abnormalities in the offspring. Nineteen of these chidren were microcephalic idiots. Eye defects, including blindness due to optic atrophy or chorioretinitis, strabismus, nystagmus, retinal pigmentation, and congenital cataract, were noted. Fifteen of these 19 children had received radiation in the first or second month of gestation. The occurrence of microcephaly in four children irradiated after the fifth month of fetal development indicates that even in the late stages of pregnancy the fetus is vulnerable to the effects of radiation. There is little doubt that a distinct relationship exists between postconception radiation and the occurrence of mental defects in the offspring.

骨盤照射が行なわれた婦人における妊娠終結の研究は，人間の胎児に関する貴重な資料を提供するに至った[18-22]。Mayer 等は，子宮の中心に 360 r の放射線1回照射を行ない，大部分の症例に治療的流産を起こさせた[21]。Murphy 等は[17-19,22] 妊婦の骨盤照射により，産児に37%（75名の小児のうち28名）という高率の知能または身体異常の発現を認めた。これら小児のうち19名は小頭白痴であって，視神経萎縮ないし脈絡網膜炎による失明，斜視，眼振，網膜色素沈着，および先天性白内障などの眼の障害があった。これら19名の小児のうち15名は，妊娠第1カ月または第2カ月で放射線照射を受けた。また妊娠5カ月を過ぎて放射線照射を受けた4名の小児における小頭症の発生は，妊娠後期においてさえも胎児は放射線の影響を受け易いことを示す。受胎後の放射線照射と産児の知能障害の発生との間には明確な関係が存在することにほとんど疑いの余地はない。

In addition to the direct effect of radiation on the developing fetus, radiation injury to maternal tissues may also exert an indirect effect upon fetal growth and development.[32,34-42,50] Radiation may cause cellular injury or death of maternal tissues by the formation of strong oxidizing agents or through inhibition of sulfhydryl enzymes. Death of maternal tissues may result in the formation of toxic products injurious to the fetal tissues.

発育中の胎児に対する放射線の直接的影響のほかに母体組織における放射線障害も，胎児の生長および発育に対し間接的影響を及ぼすであろう[32,34-42,50]。放射線は，強力な酸化剤の形成またはスルフヒドリル基酵素の抑制作用によって，細胞障害または母体組織の死をもたらすであろう。母体組織の死は，胎児組織に有害な毒性産物を形成するであろう。

Hemorrhagic phenomena in the irradiated mother resulting from damage to the vascular endothelium, destruction of platelets, or formation of heparin-like anticoagulants could adversely affect the fetus or placenta.[37-39,45,46] Fetal anoxia due to placental changes, or possible severe maternal anemia may cause irreparable damage to the fetus.[47]

脈管内皮の損傷，血小板の破壊，またはヘパリン様の抗凝固性物質の形成の結果，放射線照射を受けた母親に現われる出血性現象が，胎児または胎盤に悪影響を及ぼすこともあろう[37-39,45,46]。胎盤の変化による胎児の酸素欠乏症，ないし母体における重篤な貧血は胎児に回復不可能な損傷を起すかも知れない[47]。

Radiation-induced gastrointestinal and oropharyngeal lesions could enhance the already lowered nutritional status of the mother because of anorexia, and maternal nutritional deficiencies have been shown to cause fetal malformation in animals.[23-27]

放射線が誘発する胃腸管および口腔咽頭の病変は，食慾不振のためにすでに低下した母親の栄養状態を悪化させるであろうし，母体の栄養不足が動物における胎児の奇形を発生させることも証明済みである[23-27]。

Some aspects of the body response to radiation have been attributed to adrenal involvement and the "stress mechanism." Adrenal cortex enlargement has been demonstrated during the early stages following radiation.[41] However, as the illness continues signs of adrenal exhaustion may occur, and a clincal picture compatible with adrenal insufficiency results. This is similar to the body response to other forms of stress.[49]

放射線に対するある種の身体反応は副腎障害および「ストレッス機序」に基ずくものとされている。放射線照射後の初期段階における副腎皮質の肥大も証明された[41]。しかし，疾患が持続すればそれにつれて，副腎疲憊の徴候が現われ，その結果臨床像は副腎不全に一致する。これは他の型のストレッスに対する身体反応の場合と同様である[49]。

The efficiency of the placental barrier in protecting the fetus from maternal sepsis may be altered due to the capillary damage from radiation. Maternal infection becomes possible via ulcerated epithelial and gastrointestinal surfaces. Experimental evidence that this may occur is found in the high incidence of bacteremia in mice subjected to a lethal dose of irradiation.[35,36]

胎児を母体の敗血症から保護する胎盤関門の効率は放射線による毛細管損傷のため変化するかも知れぬ。潰瘍を起した上皮面および胃腸の表面を通して母体の感染が起り得ることになる。この可能性は致死量の放射線照射を受けたハツカネズミに菌血症が高率に発現することにより実験的にも認められている[35,36]。

During the early stages following radiation, the mother is particularly vulnerable to infection due to decreased hematopoietic activity, interference with the immune mechanisms, lowered nutritional status, and the presence of ulcerated epithelial surfaces. These serve to increase the possibility of fetal infection. In addition, the efficiency of the placental barrier in protecting the fetus from maternal sepsis may be altered due to direct capillary damage.

放射線照射後の初期段階においては，母親は造血機能の低下，免疫機序に現われる干渉，栄養状態不良および上皮面潰瘍の存在等によって，特に感染しやすくなる。これが胎児の感染の可能性を増加させる。更に胎児を母体の敗血症から保護する胎盤関門の効率は，毛細管が直接損傷を受けることによって変化するかも知れぬ。

It is difficult to correlate information that has been obtained through controlled animal experiments and careful observation of human subjects with the results of this study in which so many factors, directly or indirectly ralated to the bomb, could have had an adverse effect upon the fetus. Considerable difficulty is encountered when one tries to assess the relative importance of traumatic, thermal, and radiation injuries, inadequate nutritional intake, maternal infection, and severe psychic

対照を用いて行なう動物実験および精密な人間観察によって入手する資料と，直接的にも間接的にも原子爆弾に関連した多くの要因が，胎児に悪影響を及ぼしていると思われる本研究の諸結果に相関を求めることは困難である。外傷性，熱性および放射線性障害，不十分な栄養摂取，母体の感染および強度の精神障害，これらはいずれも胎児への危険を増すであろうが，その相対的重要性を評価しようとする場合には相当の困

disturbances, any of which would increase the hazards to the fetus. Clinical descriptions of postnatal deaths were at times vague, and pathological material was completely lacking. The authors are hesitant about allowing too liberal interpretation of these data, and have in general directed the following discussion to what must be considered as the "over-all" effect of the atomic bomb explosion upon the mother and fetus.

難に当面する。生後死亡の臨床的記述は時に不明確であり，病理学的資料は全くない。著者らはこれらの資料に対し余りに自由な解釈を加えることを躊躇するものであって，母親および胎児に対する原子爆弾爆発の「全体的」影響として考慮を要する問題の論究は，大体次のように進めた。

It is apparent from the data presented (Table 3) that when mothers received sufficient radiation to cause epilation, purpura or petechiae, and oropharyngeal lesions, their fetuses in turn had a significantly higher prenatal mortality (23.3%) when compared to fetuses of mothers who did not develop "major" signs of radiation (4.4%) or who were beyond 4,000 meters (2.7%). Among the seven fetal deaths, six occurred within a five-week period following the explosion and in each instance was associated with definite radiation illness in the mother. All of the seven fetal deaths occurred in the 19 mothers who were in the 1,001 to 1,500 meter area (Table 1). In contrast, there were only two fetal deaths among 15 mothers who had no "major" signs and were within the same area. The data suggest strongly that radiation, either directly to the fetus or indirectly through its effect on the maternal tissues, was of considerable importance in determining the incidence of fetal death in mothers with "major" radiation signs.

提示された資料（表３）によれば，脱毛，紫斑または点状出血および口腔咽頭の病変が起るほどの強烈な放射線照射を受けた母親の場合は，「主要」放射能性症候のなかった母親（4.4%）または4,000m以遠にあった母親（2.7%）から生まれた胎児に比べて，その胎児の出生前死亡率が有意に高い。７例の胎児死亡のうち，６例は原爆後５週間以内に起っており，それぞれ母親に明確なこの関連ある放射能性疾患が認められた。この７例の胎児死亡は全部1,001～1,500m の地域内（表１）にあった19名の母親の間の出来事であった。これに対して，「主要」症候がなかった同じ地域内の母親15名には，２例の胎児死亡があったに過ぎない。放射線が胎児に対して直接的にまたは母体組織に対する影響を通じて間接的に作用したことが「主要」放射能性症候をもつ母親における胎児死亡の発現率を決定する上に相当重要な役割を果していることを，これらの資料は強く示唆する。

Comparing mothers with "major" radiation signs and those without "major" signs, those mothers in the first trimester show little difference in the fetal mortality, since the numbers of cases are small. However, in the second and third trimesters, there is a definite increase in the fetal mortality rate among the group with "major" signs (Table 4).

「主要」放射能性症候のある母親と，ない母親を比較した場合，妊娠第１期の母親においては，例数がすくないため，胎児死亡率にほとんど差を認めないが，妊娠第２期および第３期においては，「主要」症候をもつ母親群の胎児死亡率が明らかに高い。（表４）

Neonatal and infant mortality was again significantly higher among infants born to mothers with "major" signs of radiation (Table 5). All of these six postnatal deaths occurred prior to the fourth month of life, and five of the six deaths involved infants whose mothers were in the 1,001

新生児および乳幼児死亡率もまた「主要」放射能性症候をもつ母親より生まれた乳幼児の間では，有意に高率であった。（表５）それら６例は，いずれも出生後４カ月までの死亡例であって，うち５例は1,001～1,500m群に属する母親から生まれた乳幼児であった。

to 1,500 meter group. Although some of the diseases are similar in symptomatology, e. g., weight loss, hemorrhagic tendencies, to that occurring in offspring of irradiated animals, the clinical descriptions were not definite enough, and pathological data were lacking. Nevertheless, there is suggestive evidence that radiation may again have had a damaging effect upon the fetus.

There is a significant increase in the neonatal and infant mortality of mothers with "major" signs who were in the second and third trimesters when compared to mothers without "major" signs (Table 4). As the numbers are small, significant differences do not exist between the two groups when exposure occurred in the first trimester.

In the group of 16 mothers with "major" radiation signs whose children survived to the present time, there were four instances of mental retardation, an incidence of 25% as compared to 1.6% and 0% in the mothers without "major" signs and in the control groups, respectively (Table 6). Three of these mothers were 1,001 to 1,500 meters from the center of the explosion, and the fourth was 850 meters.

In view of the work of Murphy and co-workers, it seems not unreasonable to assume that radiation played an important role in the etiology of these conditions.[17-19,22] One mother was exposed in the first trimester, two in the second trimester, and one in the third trimester (Table 4). The latter child was a spastic, which is of interest in the light of Hicks' observations on the marked susceptibility of the cerebellum in rats and mice irradiated at or near term.

The anthropometric measurements (Table 7) revealed that children of mothers with "major" signs were significantly smaller in height and head circumference as compared to children of the control group. The height-weight ratio within each group was unchanged. This finding is similar to animal experiments in which retardation of bone growth has been observed in irradiated rat fetuses.[43]

疾患には体重減少，出血性傾向などのように，放射線照射を受けた動物の子の場合と症候学上似ているものもあるが，臨床的記述は十分に明確でなく，病理学的資料も欠如していた。それにも拘らずここでもまた放射線が，胎児に損傷的影響を与えているかも知れないことを示唆するものが認められる。

妊娠第2期および第3期において被爆し「主要」症候のある母親から生まれた新生児および乳幼児の死亡率は「主要」症候のない母親の場合に比較して有意に高い。（表4）妊娠第1期に被爆したものについては例数が少ないから，両群の間に，有意の差は認められない。

「主要」症候は現われたが，子供が現在まで生残っている16名の母親群においては，精薄児が4例あり，「主要」症候のない母親および対照群の精薄児発現率それぞれ1.6％および0％に対して，25％の発現率を示した。（表6）これらの母親のうち3名は，爆心から1,001～1,500m，残り1名は850mの距離で被爆している。

Murphy 等の研究から見て，これらの症状の原因に放射線が重要な役割を演じていると推論して差支えないであろう[17-19]。1名の母親は妊娠第1期に，2名は第2期に，そして1名は第3期に被爆した。（表4）後者の小児は痙攣児であって，これはHicksの観察において，妊娠満期または満期に近く，放射線照射を行なったラットおよびマウスの小脳が著しく敏感であった事実に鑑み，注目に価する。

人体計測（表7）の結果によれば「主要」症候のある母親の小児は，対照群の小児と比較して身長および頭囲が著しく小さい。各群内の身長対体重の比率は不変であった。この検査所見は放射線照射を行なったラットの胎児において骨格成長の遅延が観察されたという動物実験の結果[43]と同様であった。

SUMMARY

A study has been made of the outcome of pregnancy in women who were pregnant at the time of the atomic bomb explosion in Nagasaki. Among 30 mothers with one or more "major" signs of radiation, i. e., epilation, oropharyngeal lesions, purpura, or petechiae, who were within 2,000 meters of the hypocenter, there were 7 fetal deaths (23.4%), 6 neonatal and infant deaths (26%), and 4 instances of mental retardation among 16 surviving children (25%). The over-all morbidity and mortality is approximately 60% in this group of mothers. This is in sharp contrast to the group of mothers without "major" signs but within 2,000 meters, where the over-all mortality was only 10%, and in the control group, where it was about 6%.

In the second and third trimesters there is a significantly greater fetal, neonatal, and infant mortality among the mothers with "major" signs when compared to the mothers without "major" signs or the control group.

The mean height and head circumference of children born to mothers with "major" signs was significantly smaller than in those children born to mothers in the control group.

It is difficult to evaluate the effect of radiation on this mortality and morbidity, since other factors, such as trauma, burns, infections, etc., may have a deleterious effect on the fetus. The evidence strongly suggests, however, that radiation either directly to the fetus, or indireectly as a result of its effect on the maternal tissues, was of considerable importance in determining the outcome of these pregnancies.

総　　括

長崎における原爆被爆女性の妊娠結果を調査した。爆心地から2,000m以内にあって被爆し，「主要」放射能性症候，すなわち，脱毛，口腔咽頭の病変紫斑または点状出血が1つ以上現われた30名の母親に，胎児死亡7例（23.4%），新生児および乳幼児死亡6例（26%），並びに生残った16名に精薄児4例（25%）を認めた。この母親群における全罹病率および死亡率は約60%である。これは2,000m以内で被爆した「主要」症候のない母親群では全死亡率がわずかに10%，対照群では6%であったのと比べて著しい対照を成す。

妊娠第2期および第3期においては，「主要」症候のない母親または対照群と比較した場合，「主要」症候のある母親の間では，胎児，新生児および乳幼児の死亡率が有意に高い。

「主要」症候をもつ母親に生まれた小児の平均身長および頭囲は，対照群の母親に生まれた小児の場合よりも有意に小さい。

外傷，火傷，感染等の他の要因も，胎児に対し有害な影響を及ぼすであろうから，上記の死亡率および罹病率に対する放射線の影響を評価することは困難である。しかし，放射線が胎児に対して直接，または母体組織への影響の結果として間接的に作用したことが，これら妊娠の結果の決定に相当重要な役割を演じていることを強く示唆するものが認められる。

ADDENDUM

Since the completion of this study, Plummer has investigated the health of 205 children in Hiroshima who had been exposed to the atomic explosion during the first half of intrauterine life (Pediatrics 10 : 693, 1952). Seven of the 11

補　　遺

本研究が完了して以後，Plummer は，胎児期前半において，原子爆発に被爆した205名の広島小児の健康調査を行なった（Pediatrics誌 10：693，1952）。爆心から1,200m以内で被爆した11名の小児のうち7名

children who were exposed within 1,200 meters of the hypocenter had mental retardation. All seven of these children had mean head circumferences below 45 cm., in contrast to 171 normal exposed children whose mean head circumference was 48.6 ± 1.3 cm. Only one case of mental retardation was noted among the remaining 194 children, and this child was exposed between 2,500 and 3,000 meters.

Among the 11 exposed mothers, 7 had definite symptoms of epilation or purpura, and of these, 5 had children with mental and physical retardation. Shielding may have been effective in preventing fetal injury among the remaining four mothers, whose infants were normal.

This study represents the combined efforts of many members of the Atomic Bomb Casualty Commission in Nagasaki and Hiroshima. Valuable criticism and assistance from the professional and biostatistical staff of the Commission are acknowledged. Mention must be made, in particular, of the help given by the Japanese physicians and others, including Dr. Takao, Dr. Hamada, Dr. Neriishi, Dr. Yasuda, Mr. Hamasaki, and Mr. Noble, whose assistance in history-taking and interpretation of local customs greatly facilitated the completion of this study. The authors are also indebted to Dr. A. E. Lewis, Atomic Energy Commission, University of California at Los Angeles, who gave valuable assistance in preparing the statistical analyses.

が精薄児であった。これら7名の小児の平均頭囲は，45cm以下であったが，これに対して同じく被爆した正常児171名の平均頭囲は，48.6±1.3cmであった。残りの194名の小児には，精薄児はわずか1名認められたに過ぎない。この小児は2,500～3,000mの間で被爆していた。

被爆した母親11名のうち，7名に脱毛または紫斑の明確な症状があり，うち5名の子供には，知能ならびに身体的発育の遅延が認められた。残り4名の正常児の母親では，効果的な遮蔽があったために胎児が障害を免がれたものであろう。

本研究は広島および長崎における原爆傷害調査委員会の多くの職員の協力の賜物である。同委員会の専門職員および生物統計学職員から寄せられた貴重なる批判並びに援助を感謝する。高尾，浜田，錬石，安田，浜崎およびMr. Noble等日本人医師その他から受けた助力に対しては特に言及しておきたい。これらの人々が病歴の記録採取および地方風習の解釈に当って与えられた援助は，本研究の完成を極めて容易にした。著者らはまた統計学的解析を準備するに当り，貴重なる援助を与えられたLos Angeles，加州大学の原子力委員会，委員Dr. A. E. Lewisに負う所多大であった。

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