FOREIGN BODIES RADIOGRAPHICALLY-DEMONSTRATED IN ATOMIC BOMB SURVIVORS

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原爆被爆生存者にX線学的に証明された異物

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原爆被爆者にX線学的に証明された異物の頻度を，原爆爆風による傷害の指標として調査した．また，これらの人々にみられた鉱異物の頻度は，被爆によつて起こるとみられる体の異常の指標と

して調査された．

異物の認められたすべての成人健康調査対象者のX線写真が再検討された．様々の異物の内，ガラス，金属，鍼の頻度について詳細な解析が行われた．この解析は爆心地からの距離，性，被爆時年齢，異物のみられた身体の部位，被爆時の遮蔽状態について行われた．

ガラス異物の頻度と，爆心地からの距離，被爆時の遮蔽状態及び年齢との間に密接な相関が認められ，ガラス異物は身体の部位では手よりも胸部に多くみられた．これに反して，金属異物は胸部より手に多く，その頻度と爆心地からの距離や被爆時の遮蔽状態との間に統計的に有意な関係はみられなかつた．

鍼異物の頻度は，高年齢になるにつれて増加するが，被曝線量との間に相関はみられなかつた．

Abstract

The prevalence of roentgenologically-detected foreign bodies among atomic bomb (A-bomb) survivors was studied as an indicator of the A-bomb blast effects. Acupuncture was studied as an indicator of A-bomb-related abnormalities for which it was administered. All Adult Health Study subjects' roentgenograms demonstrating foreign bodies were reviewed. The frequency of glass and metal, and acupuncture needles were analyzed by distance from hypocenters, sex, age, body sites involved; and the subjects' shielding at the times of the A-bombs. The presence of glass fragments correlated closely with distance from hypocenter, heavy shielding from the A-bombs, and with adulthood, and they were more frequent in the chest than hand and wrist. Metal foreign bodies were more frequent in the hand and wrist than in the chest, and not associated with distance from hypocenter or heavy shielding. The prevalence of acupuncture needles increased with age, but did not correlate with A-bomb dose.

Background

Several types of foreign bodies have been radiologically-demonstrated in participants of the Radiation Effects Research Foundation's (RERF) Adult Health Study (AHS)[1] in Hiroshima and Nagasaki. These foreign bodies can conceivably reflect some of the subjects' life experiences, including their injuries at the times of the atomic bombs (ATB). In this investigation we studied the relation of sources of the foreign bodies in A-bomb survivors to events ATB. The foreign bodies were considered possibly to be related to the distance of the survivors from the hypocenters and their types of shielding ATB. Histories of glass cuts ATB which were collected in an earlier survey were used in this study.

Method and Material

The RERF AHS is a large scale long-term clinical investigation for detecting late effects of the A-bombs among Hiroshima and Nagasaki survivors, originally numbering 20,000[1]. All subjects biennially receive complete physical examinations and laboratory studies. Posteroanterior stereoscopic and lateral chest roentgenography are included. Examinations of other body sites, including radiography and fluoroscopy, are also performed when clinically indicated.

From 1 July 1962 to 30 June 1974 all diagnoses made in the Department of Radiology, including any foreign bodies detected, were coded using the Index for Roentgen Diagnosis of the American College of Radiology[2]. The Department of Epidemiology and Statistics supplied a list of all cases with foreign bodies coded during this period.

All available roentgenograms of individuals previously coded as demonstrating the presence of foreign bodies were reviewed. The foreign bodies were classified by type and by body site in which they were imbedded. The most frequent foreign bodies were glass, metal, and acupuncture needles. Their occurrence was studied in the chest, hand and wrist, and abdomen.

For the purposes of this study, shielding was classified as "light" and "heavy" based on whether the person was or was not protected from the effects of the blast; i.e., flying debris[3]. "Heavy shielding" was coded when the person was totally protected; for example, inside a wooden building, a concrete building, or an air-raid shelter. "Light shielding" consisted of partial or no protection; for example, in the open, or standing in a doorway, or near a window of a building.

The frequencies of glass and metal foreign bodies in the chest, and in the hand and wrist were analyzed by sex, by distance from the hypocenter, by age, and by the subjects' shielding configuration ATB. The occurrence of radiologically-detected glass foreign bodies was compared with the history of glass cuts ATB to determine the possible sources of the foreign bodies. Frequencies of acupuncture needles in the chest and abdomen were analyzed by the age of the subjects and by radiation dose[4].

Results

From 1 July 1962 to 30 June 1974, 615 AHS subjects in Hiroshima and Nagasaki were recorded as having foreign bodies. For the present analysis the following persons were excluded: 63 with calcified lymph nodes and temporarily-retained ingested barium; 30 with injected Salvarsan in their buttocks; one female with opaque-foreign material in her left breast for cosmetic reasons; 42 with post-surgical clips and orthopedic fixation devices, and 55 with retained-contrast media from previous myelography or lymphography.

Four hundred and sixty-three had the most frequently observed foreign bodies including glass, metal, and acupuncture needles; 140 had metal; 196 had glass; and 127 had acupuncture needles. Some patients had more than one type of foreign body in the same or different body sites.

Table 1 shows the distribution of metal and glass foreign bodies and acupuncture needles by body site. Foreign bodies were radiologically-demonstrated in 14 body sites, but they occurred with the greatest frequency in examinations of the chest, of the abdomen and pelvis, and in the hand and wrist. The relatively large numbers of foreign bodies in the chest were due in part to the fact that all subjects received chest radiography routinely every two years and radiography of other body sites only as clinically indicated. The foreign bodies found in the chest, hands and wrists were therefore subjected to more detailed analyses.

Glass

Table 2 shows the frequency of glass foreign bodies in the chest and in the hand and wrist among A-bomb exposed subjects, according to distance from the hypocenter. The numbers of subjects with and without histories of glass cuts ATB are also shown. Only one case of glass foreign bodies in the chest occurred among nonexposed subjects. The frequency of glass foreign bodies was greater among the A-bomb exposed than the nonexposed, and decreased with increasing distance from the hypocenter. This tendency was seen only for subjects with glass cuts ATB. Glass foreign bodies were more frequent in the chest than in the hand and wrist, a point to be discussed later in this report.

Table 1. Number of persons with radiologically confirmed foreign bodies by body site, 1962–74

Site	Total examined	Cases with foreign bodies		
		Metal	Glass	Acupuncture
Chest	14,426	49	131	60
Shoulder	458	1	5	4
Arm	12	—	3	—
Elbow	339	—	9	1
Forearm	26	1	1	—
Hand & wrist	2,305	66	14	3
Knee	1,206	8	6	10
Leg	62	—	1	—
Ankle & foot	590	5	1	3
Cervical spine & soft tissue	451	1	6	1
Abdomen*	6,076	9	16	43
Pelvis	275	—	1	2
Skull	441	—	2	—
Other	1,414	0	—	—
Total	28,081	140	196	127

*Includes lumbosacral spine, gallbladder, gastrointestinal, intravenous pyelogram, and barium enema.

Table 2. Glass foreign bodies by body site, distance from hypocenter and glass cuts reported ATB

Body site	Foreign body	Distance in meters						Total exposed
		0–749	750–999	1,000–1,249	1,250–1,499	1,500–1,999	2,000+	
Chest	Total	9	15	37	45	18	6	130
		(3.27)	(2.78)	(2.25)	(1.77)	(0.83)	(0.16)	(1.19)
	Glass cut	9	8	30	33	15	0	95
	(+)	(9.7)	(6.6)	(7.1)	(5.1)	(3.7)	(0.0)	(5.6)
	Glass cut	0	4	1	5	1	0	11
	(−)	(0.0)	(1.2)	(0.1)	(0.6)	(0.1)	(0.0)	(0.3)
	Glass cut Unknown	0	3	6	7	2	6	24
Hand & wrist	Total	1	0	5	5	2	1	14
		(2.27)	(0.0)	(1.77)	(1.12)	(0.55)	(0.17)	(0.78)
	Glass cut	1	0	4	3	1	0	9
	(+)	(5.9)	(0.0)	(5.1)	(2.4)	(1.4)	(0.0)	(2.8)
	Glass cut	0	0	1	1	1	0	3
	(−)	(0.0)	(0.0)	(0.6)	(0.4)	(0.5)	(0.0)	(0.4)
	Glass cut Unknown	0	0	0	1	0	1	2

The numbers in parenthesis are percentages of subjects with foreign bodies among examined subjects within given distance of hypocenter.

Table 3. Number of persons with glass foreign bodies by distance from hypocenter, sex and body site

Body site	Sex	Distance in meters						Total exposed
		0–749	750–999	1,000–1,249	1,250–1,499	1,500–1,999	2,000+	
Chest	Total	9	15	37	45	18	6	130
		(3.3)	(2.8)	(2.2)	(1.8)	(0.8)	(0.2)	(1.2)
	Male	3	8	17	16	5	1	50
		(2.9)	(3.6)	(2.6)	(1.7)	(0.6)	(0.1)	(1.2)
	Female	6	7	20	29	13	5	80
		(3.5)	(2.2)	(2.0)	(1.8)	(0.9)	(0.2)	(1.2)
Hand & wrist	Total	1	0	5	5	2	1	14
		(2.3)	(0.0)	(1.8)	(1.1)	(0.5)	(0.2)	(0.8)
	Male	1	0	2	3	0	1	7
		(9.1)	(0.0)	(2.5)	(2.2)	(0.0)	(0.6)	(1.2)
	Female	0	0	3	2	2	0	7
		(0.0)	(0.0)	(1.5)	(0.6)	(0.8)	(0.0)	(0.6)

The numbers in parenthesis are percentages of subjects with foreign bodies among examined subjects within given distance of hypocenter.

Table 4. Number of persons with glass foreign bodies by body site, type of shielding, and distance from hypocenter

Body site	Shielding	Total	Distance in meters	
			<1,250	1,250+
Chest	Light	16	5	11
		(1.08)	(1.22)	(1.03)
	Heavy	105	55	50
		(2.12)	(3.07)	(1.58)
Hand & wrist	Light	0	0	0
		(0.0)	(0.0)	(0.0)
	Heavy	12	6	6
		(1.38)	(1.86)	(1.10)

The numbers in parenthesis are percentages of subjects with foreign bodies among examined subjects within given distance of hypocenter.

The glass foreign bodies in each body site were analyzed by sex (Table 3). There was no statistically significant difference in the frequency of glass foreign bodies in the chest or in the hand and wrist by sex.

Shielding information was available for 133 of the 196 subjects with glass foreign bodies, and for 70 of the 140 with metal foreign bodies. Tables 4 and 7 show the prevalence of these types of foreign bodies by type of shielding data available. As shown in Table 4, glass foreign bodies increased in prevalence among persons who were well-shielded. This association was statistically significant. The difference in frequency between the light- and heavily-shielded was more prominent for those who were within 1,250 m from the hypocenters ATB.

The study subjects were divided into two age groups; those under 15 years of age, and those 15 years old and older ATB. Glass foreign bodies in the chest occurred more frequently in those 15 years and older (Table 5). The association between the occurrence of glass foreign bodies and distance from the

Table 5. Percent of cases with glass foreign bodies in chest by distance from hypocenter and age ATB

Age	Distance in meters						Total exposed
	0–749	750–999	1,000–1,249	1,250–1,499	1,500–1,999	2,000+	
	%	%	%	%	%	%	%
Total	3.27	2.78	2.25	1.77	0.83	0.16	1.19
<15 years	0.0	0.79	0.92	1.14	0.20	0.0	0.45
15+ years	3.83	3.35	2.57	1.90	1.01	0.20	1.37

Table 6. Number of persons with metal foreign bodies by distance from hypocenter, sex, and body site

Body site	Sex	Distance in meters						Total exposed	NIC*
		0–749	750–999	1,000–1,249	1,250 1,499	1,500–1,999	2,000+		
Chest	Total	0	1	8	11	9	7	36	13
		(0.0)	(0.2)	(0.5)	(0.4)	(0.4)	(0.2)	(0.3)	(0.4)
	Male	0	0	4	8	5	7	24	11
		(0.0)	(0.0)	(0.6)	(0.8)	(0.6)	(0.5)	(0.6)	(0.8)
	Female	0	1	4	3	4	0	12	2
		(0.0)	(0.3)	(0.4)	(0.2)	(0.3)	(0.0)	(0.2)	(0.1)
Hand & wrist	Total	2	0	7	19	18	12	58	8
		(4.5)	(0.0)	(2.5)	(4.3)	(4.9)	(2.1)	(3.2)	(1.6)
	Male	1	0	4	14	13	10	42	5
		(9.1)	(0.0)	(5.0)	(10.3)	(11.6)	(5.8)	(7.8)	(3.3)
	Female	1	0	3	5	5	2	16	3
		(3.0)	(0.0)	(1.5)	(1.6)	(2.0)	(0.5)	(1.3)	(0.8)

The numbers in parenthesis are percentages of subjects with foreign bodies among examined subjects within given distance of hypocenter.
*Not-in-city

hypocenter was found only in those 15 years and older.

Metal

Table 6 shows the number and frequency of metal foreign bodies in the chest, and in the hand and wrist among A-bomb exposed and nonexposed subjects.

Among nonexposed subjects the rate of metal foreign bodies was greater than that of glass ones. Metal foreign bodies in the hand and wrist were more frequent among exposed than nonexposed subjects, and this difference was statistically significant. Such a difference was not seen for those in the chest.

The foreign bodies in each body site were analyzed by sex. Metal foreign bodies were much more prevalent in males than in females, and this was particularly true for the hand and wrist. Metal foreign bodies were more frequent in the hand and wrist than in the chest, but in neither case was there any heterogeneity with respect to distance from hypocenter. As with glass, metal foreign bodies occurred more frequently in those who were well-shielded (Table 7), and in those 15 years of age and older ATB (Table 8). Whereas, glass foreign bodies were more prevalent in those who were heavily shielded and within 1,250 m from the hypocenters (Table 4), there was no definite difference in frequency by distances

Table 7. Number of persons with metal foreign bodies by type of shielding, body site, and distance from hypocenter

Body site	Shielding	Total	Distance in meters	
			<1,250	1,250+
Chest	Light	4	1	3
		(0.27)	(0.24)	(0.28)
	Heavy	22	6	16
		(0.44)	(0.34)	(0.50)
Hand & wrist	Light	8	2	6
		(3.43)	(4.35)	(3.21)
	Heavy	36	7	29
		(4.15)	(2.17)	(5.32)

The numbers in parenthesis are percentages of subjects with foreign bodies among examined subjects within given distance of hypocenter.

Table 8. Number of persons with metal foreign bodies by age ATB and body site

Age	Chest	Hand & wrist
<14	1	5
	(0.0)	(1.5)
15+	48	61
	(0.4)	(3.1)

The numbers in parenthesis are percentages.

Table 9. Number of persons with acupuncture needles by age in 1962 and body site

Body site	Total	Age in years			
		<40	40–54	55–64	65+
Chest	60	17	18	21	4
	(0.42)	(0.26)	(0.46)	(0.77)	(0.31)
Abdomen	43	12	10	15	6
	(0.71)	(0.48)	(0.56)	(1.16)	(1.16)

The numbers in parenthesis are percentages.

Table 10. Number of persons with acupuncture needles by T-65 dose and body site

Body site	T-65 dose in rad					
	NIC*	0	1–99	100–199	200+	Unknown
Chest	15	15	17	3	8	2
	(0.43)	(0.41)	(0.42)	(0.25)	(0.57)	(0.40)
Abdomen	5	11	17	3	7	0
	(0.35)	(0.71)	(0.95)	(0.58)	(1.21)	(0.00)

The numbers in parenthesis are the age-adjusted rate.
*Not-in-city

from hypocenters for metal.

Acupuncture Needles

The prevalence of acupuncture needles increased slightly with age, but there was no definite trend with A-bomb dose (Tables 9 and 10). Though acupuncture needles, if left in the soft tissues, usually remain unchanged in location and appearance for the remainder of the individual's life, they can migrate—as along fascial planes. They may increase in number with age, with repeated treatments. Lack of definite correlation permits various interpretations and impressions.

Discussion

In Hiroshima, it was warm at 8: 15 A.M. 6 August 1945. Many people were outside, and their light clothing afforded them little protection. No air raid was expected, and consequently the shelters were practically empty. There was an instantaneous glare at the moment of the explosion, followed by intense permeating heat. After a short interval, a violent shock wave flattened the fragile wooden houses[5].

In Japanese style structures, the likelihood of severe trauma was greater from the large longitudinal beams which supported the "arch" or "tie" beams. Shoji, the sliding partitions, consist of a wooden frame accommodating numerous small, thin glass or paper panels. Such glass splintered into long, spear-shaped penetrating fragments[5].

The seemingly massive concrete buildings were heavily damaged. Within 1,000 m of the hypocenter, concrete buildings were safer than wooden ones in terms of ultimate survival, but casualties from trauma were heavy. Windows were larger and more numerous in concrete buildings than in wooden houses. In concrete buildings, trauma was incurred mainly because of the flimsily constructed building partitions, by the trim on ceilings and walls, and particularly, by the flying glass[5]. Following the blast and secondary fires in Hiroshima, only 50 reinforced concrete buildings remained standing in the central area, but they were heavily damaged[5].

Damage to structures by the explosions was similar in both cities, except for some shielding offered by some of the hilly Nagasaki terrain[6]. Analysis of data from both cities revealed that mechanical injuries were minimal among individuals outside and unsheltered[5]. Mechanical injuries were incurred directly from the blast, or indirectly from falling debris. They were greatest among those who were indoors in heavy buildings[5].

Radiographic demonstration of glass depends to some extent on the size of the fragment and the density of the body site in which it is imbedded. In spite of the misconception that glass fragments cannot be demonstrated roentgenologically unless they contain lead or other heavy metals, all glass—regardless of type or lead content—is relatively radiopaque and should be visible on a radiograph made with proper exposure and positioning[7)-9)]. We therefore conclude that we have detected nearly all the glass foreign bodies in roentgenologically-examined AHS subjects.

Glass foreign bodies were very infrequently found among nonexposed subjects; among exposed survivors, the frequency of glass decreased with increasing distance from the hypocenter. No significant sex difference was found in the occurrence of glass foreign bodies. This probably meant that the frequency of glass foreign bodies did not depend on occupational or other social conditions. These findings strongly suggest that the glass fragments were imbedded ATB.

We further analyzed the data for subjects with glass foreign bodies according to two groups: Those who reported glass cuts ATB and those who did not. The former group probably obtained their glass foreign bodies ATB; those without glass cuts ATB probably obtained their glass fragments from other sources. The former group was larger and the frequency of glass foreign bodies decreased with increasing distance from the hypocenters. For the latter group, no such correlation was found. This provides further evidence that the major portion of theg/ass foreign bodies was due to A-bomb exposure.

Glass foreign bodies were more frequent among those who were heavily shielded ATB. This phenomenon was more prominent for subjects who were within 1,250 m from the hypocenters. This greater prevalence of glass foreign bodies among heavily shielded subjects may have been due to construction materials impelled by the A-bomb blasts.

Glass foreign bodies were found more frequently among those 15 years and older ATB. This is attributable to body size and shielding at that time. Many adults were presumably in comparatively heavily shielded situations, such as factories. However, buildings were frequently of relatively light construction, having often been constructed of corrugated metal on metal framework, rather than of reinforced concrete.

Glass foreign bodies were more frequently found in the chest as opposed to the hand and wrist, because the target area of the chest is relatively large compared to those of the hands and wrists, and accordingly, more subject to injury by propelled objects. Also, glass may be more easily imbedded in the chest than metal assuming it can penetrate clothing more easily.

On the contrary, metal foreign bodies were observed more frequently in the hands and wrists than in the chest. No definite correlation could be established between the frequency of metal foreign bodies and distances from the hypocenters.

Among nonexposed subjects, metal foreign bodies were found more frequently than glass ones, but there was no difference in the frequency of metal fragments in the chest for the exposed and nonexposed subjects. This suggests that the metal foreign bodies were due to sources other than the A-bombs, such as during military service or from occupational accidents.

Metal fragments were much more frequent in males, and more frequent in the hands and wrists than in the chest, probably because the hands and wrists were not shielded by clothing, and because the risk of injury was higher for those who were engaged in manual work. These findings further support the concept that metal foreign bodies were more frequently due to sources other than the A-bombs. Although metal foreign bodies were more frequent in those 15 years and older ATB, we have no evidence that, because of blast effects, they were more prevalent among adults. This prevalence was probably due rather to the greater opportunities for entry of metal foreign bodies during their relatively long life spans, their prolonged occupations, and their periods of military service. Those who were working ATB may have been more heavily shielded, although we have no proof of this.

As with glass, there was a slightly greater frequency of metal fragments in those more heavily shielded, but there was no correlation with distance from hypocenter. This also suggests that the blast effects of the A-bombs played only a small role in the imbedding of metal foreign bodies.

Acupuncture needles were also found in these subjects. Japanese acupuncture is based on ancient Chinese medicine. Although Western medicine currently prevails in Japan, some ancient Chinese

medical practices are still used[10]. Acupuncture is considered indicated for various disorders, including those of the nervous, circulatory, alimentary, respiratory and gynecological systems[11].

Acupuncture purportedly aims at the eradication of the symptoms of a disease, rather than at its cure. Silver and gold are most frequently used in the manufacture of acupuncture needles, particularly silver. The needles range from approximately 3 to 9 cm in length, and from 0.33 to 3.17 mm in diameter[11]. Acupuncture needles could be indicative of earlier treatment for symptoms related to injuries and to ionizing radiation produced by the A-bombs. However, while our study disclosed that the prevalence of imbedded acupuncture needles increased slightly with age, there was no definite trend between frequency and A-bomb dose.

Acupuncture needles are usually imbedded in body sites considered appropriate, then manipulated, and withdrawn. They will remain in the tissue, when they are either accidentally or deliberately broken off during treatment. Those deliberately broken are the so-called "sacrifice needles" used by some acupuncturists[10]. Roentgenologically-demonstrated acupuncture needles are therefore not good indicators of the total number of needles inserted, the total treatments administered, nor the symptoms for which acupuncture was performed.

In conclusion, glass, metal, and acupuncture needles were the most frequent foreign bodies in the AHS sample population. Glass foreign bodies were closely related to the subjects' injuries due to the A-bomb blasts. No significant correlation was established between the prevalence of metal foreign bodies and the A-bombs. Metal foreign bodies were apparently due to sources other than the A-bombs, such as during military service or from occupational accidents. The prevalence of acupuncture needles increased slightly with the subjects' ages but no definite trend was established as to their frequency and A-bomb dose.

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