

8. Lawrence, R. A., and Merritt, T. A.: Infants of adolescent mothers: perinatal, neonatal, and infancy outcome. *In* Premature adolescent pregnancy and parenthood, edited by E. R. McAnarney. Grune and Stratton, New York, 1983, pp. 149-168.
9. Monkus, E., and Bancalari, E.: Neonatal outcome. *In* Teenage parents and their offspring, edited by K. G. Scott, T. Field, and E. Robertson. Grune and Stratton, New York, 1981, pp. 131-144.
10. Rothenberg, P. B., and Varga, P. E.: The relationship between age of mother and child health and development. *Am J Public Health* 71: 810-817 (1981).
11. Zuckerman, B., et al.: Neonatal outcome: is adolescent pregnancy a risk factor? *Pediatrics* 71: 489-493 (1983).
12. Placek, P.: The 1980 National Natality Survey and National Fetal Mortality Survey—methods used and PHS agency participation. *Public Health Rep* 99: 111-116, March-April 1984.
13. Baldwin, W., and Cain, V. S.: The children of teenage parents. *Fam Plann Perspect* 12: 34-43 (1980).

Radiation Procedures Performed on U.S. Women During Pregnancy: Findings from Two 1980 Surveys

PEGGY M. HAMILTON, BS
 PAUL L. RONEY, BA
 KENNETH G. KEPPEL, PhD
 PAUL J. PLACEK, PhD

Ms. Hamilton and Mr. Roney are statisticians at the Division of Life Sciences, Office of Science and Technology, National Center for Devices and Radiological Health, Food and Drug Administration. Dr. Keppel and Dr. Placek are statisticians in the Division of Vital Statistics, National Center for Health Statistics.

The paper was presented November 16, 1983, at the American Public Health Association meeting in Dallas, Tex.

Tearesheet requests to Ms. Hamilton, National Center for Devices and Radiological Health, HFZ 116, 5600 Fishers Lane, Rockville, MD 20857.

Synopsis

The 1980 National Natality Survey (NNS) and 1980 National Fetal Mortality Survey (NFMS) provide a

unique opportunity to examine variation in exposure to radiation during pregnancy for mothers of live-born and stillborn infants. Maternal race, age, education, and marital status in both surveys and low birth weight in the 1980 NNS are characteristics used to examine exposure rates for X-ray, ultrasound, nuclear medicine, short-wave, and microwave radiation examinations and treatments.

About 15 percent of mothers of live infants and 23 percent of mothers who experienced stillbirths (fetal deaths of 28 weeks or more gestation) had a medical X-ray procedure during pregnancy. The 15 percent exposed in 1980 was a reduction from 22.5 percent of mothers exposed according to the results of the 1963 NNS; this reduction occurred in all race and age groups. About 34 percent of 1980 NNS mothers and 53 percent of 1980 NFMS mothers had ultrasound exposure during pregnancy. Radiation exposure rates were higher for 1980 NNS mothers who had low birth weight infants (under 2,500 g, or 5 lb, 8 oz) than for those who had normal weight infants.

BECAUSE PREGNANT WOMEN ARE EXPOSED to radiation, public health programs that promote judicious use of radiation equipment in the United States require estimates of the number and characteristics of women examined or treated with radiation, frequency of their visits, and types of examinations. Numerous studies have stressed the need for caution in exposing pregnant women to radiation. As a result of these studies, major public awareness campaigns have been instituted, particularly for X-ray examinations and treatments, since studies have shown a risk of childhood cancer as the result of exposure to X-rays in utero (1-3). Subtle effects of exposure to ultrasound in utero have also been noted in

laboratory animals (4,5). The results of studies of the effects of ultrasound in human beings, although suggestive, remain controversial (6-9).

Studies of X-ray exposure among the general population (10-12) were conducted in 1960, 1964, and 1970 by the National Center for Devices and Radiological Health (NCDRH) in cooperation with the National Center for Health Statistics (NCHS). However, these studies gave scant information on the exposure of pregnant women. To estimate the exposure of women to X-rays during pregnancy, the NCDRH and NCHS designed the 1963 National Natality Survey (NNS), the first national natality "followback" survey. (Followback refers to

contacting informants by mail who were identified on vital records.) In the 1963 NNS, a sample of birth certificates for 1963 was drawn, and information on exposure to X-rays was sought from mothers and their medical sources (13,14). A substantial amount of information on X-ray exposure was collected for this national probability sample of live births, which resulted in estimates of the number of women exposed, their characteristics, and the nature of their exposures. Until the 1980 NNS, the 1963 NNS was the only source of national estimates of X-ray exposure among pregnant women.

The NCDRH supported the 1980 National Natality and Fetal Mortality Surveys (NNS-NFMS) to obtain current information on the exposure of pregnant women to specific types of radiation examinations and treatments. The 1980 NNS was designed to obtain X-ray exposure information comparable with that of the 1963 NNS. The 1980 NFMS obtained the first information on radiation exposure for a national sample of mothers of stillborn infants (fetal deaths of 28 weeks or more gestation). The 1980 NNS-NFMS sought radiation exposure information for medical X-ray, dental X-ray, ultrasound, nuclear medicine, shortwave, and microwave examinations and treatments. The 1980 NNS-NFMS are the first sources of national estimates of exposure to the new types of radiation among pregnant women who have live-born and stillborn infants.

Methods and Data Limitations

The 1980 NNS-NFMS were general purpose sample surveys based on information from vital records and from mail questionnaires returned by mothers, hospitals, physicians, and other providers of medical care. Questionnaires mailed to married mothers asked whether they had received specific types of radiation examinations and treatments (including dental X-rays) during the year preceding their 1980 delivery. They were asked to list the

'The 1980 National Natality and Fetal Mortality Surveys are the first sources of national estimates of exposure to the new types of radiation among pregnant women who experience live births and still births.'

names and addresses of the providers of these examinations and treatments.

Independently, questionnaires for both married and unmarried mothers were sent to the hospitals where the deliveries occurred and to attendants at delivery if they were not apparently on the hospital's staff. In addition to questions about prenatal care and the delivery, the questionnaires asked whether the mother had been exposed to microwave or shortwave radiation, and requested detailed information on all medical X-rays, ultrasound, and nuclear medicine procedures that the mother had received there. Hospitals and physicians were also asked to identify other medical sources where the mother might have received radiation examinations and treatments. Questionnaires were sent to these additional sources named by the mother, the hospital, and the physician. In addition to the radiation questions in the hospital and physician questionnaires, information on dental X-rays was requested from these additional sources. The nature of the 1980 NNS-NFMS information on radiation is summarized in table 1. For a more complete discussion of the methods used, see "The 1980 National Natality Survey and National Fetal Mortality Survey—Methods Used and PHS Agency Participation," also in this issue.

Missing data due to nonresponse were imputed by using complex procedures designed to attribute the radiation exposure reported by responding sources to nonres-

Table 1. Data items collected for each radiation procedure and radiation modality, United States, 1980

Data	Medical X-ray	Dental X-ray	Ultrasound	Nuclear medicine	Shortwave and microwave
Date of examination	X	X	X	X	...
Indication for use	X	X	X	X	...
Primary body area exposed	X	...	...	...	...
Type of procedure	X	X	X	X	...
Type of examination	X	...	X	...	...
Number of films	X	X	...	...	...
Use of procedure	...	...	X	X	X
Amount of radionuclide	...	...	...	X	...
Type of radionuclide	...	...	...	X	...

¹ X = data items collected; ... = data items not collected.

ponding sources. These procedures were designed to compensate for the fact that unmarried mothers were not sent questionnaires and thus could not identify additional medical providers of radiation. The 1980 NNS–NFMS data have been weighted to reflect national estimates of radiation exposure among women who experienced live births and stillbirths in 1980. These estimates of exposure rates may be understated to the extent that respondents failed to identify all medical providers of mothers' radiation examinations and treatments.

Although information was collected on radiation exposure during the 12 months before delivery, this report is limited to procedures during gestation. Our estimates, therefore, represent potential exposure of the fetus in utero. The objective of this report is to present basic data on exposure rates of women during pregnancy according to their characteristics. Information is given separately for mothers who had live-born and stillborn infants. No conclusions concerning the effects of radiation should be drawn from differences in the observed exposure rates between live births and stillbirths.

Findings

Exposure to radiation. In 1980, there were 3,612,258 live births to U.S. residents. An estimated 44 percent, or 1,589,000, of these mothers were exposed to some form of radiation during pregnancy (tables 2 and 3). The percentages of mothers exposed to radiation were higher among mothers who had low birth weight infants (less than 2,500 g); this difference was more pronounced for married mothers than for unmarried mothers.

There were an estimated 19,202 stillbirths in the United States during 1980. Based on the 1980 NFMS,

we estimated that 12,097 of the mothers (63 percent) were exposed to some form of radiation during pregnancy. The percentage of married mothers exposed was greater than the percentage of unmarried mothers exposed (65.5 versus 54.4 percent). The difference in exposure rates between live births and stillbirths is the result of higher rates of exposure to medical X-rays and ultrasound among women who experienced stillbirths. These higher exposure rates may be associated with attempts to detect fetal demise.

X-ray exposure: 1980 and 1963. In 1980, 15 percent of the mothers of live-born infants were exposed to medical X-rays during pregnancy. Figures for this group

Table 3. Mothers of stillborn infants who were exposed to radiation during pregnancy, according to marital status, United States, 1980

Type of radiation exposure	Total	Married	Not married
Number of women . . .	19,202	14,793	4,409
Percent exposed:			
Any radiation	63.0	65.5	54.4
Medical X-rays	23.4	24.4	20.3
Dental X-rays	2.4	2.7	1.6
Ultrasound	53.4	55.8	45.6
Nuclear medicine ..	1.3	1.3	1.3
Shortwave	1.4	1.4	1.2
Microwave	1.1	1.1	1.1

¹ Figure does not meet standards of reliability or precision; that is, the relative standard error is 25 percent or more.

Table 2. Mothers of live-born infants who were exposed to radiation during pregnancy, according to marital status and birth weight, United States, 1980

Type of radiation exposure	Total			Married			Not married		
	Total	Less than 2,500 grams	2,500 grams or more	Total	Less than 2,500 grams	2,500 grams or more	Total	Less than 2,500 grams	2,500 grams or more
Number of women . .	3,612,000	247,000	3,365,000	2,945,000	170,000	2,775,000	660,000	77,000	590,000
Percent exposed:									
Any radiation	44.0	53.9	43.3	44.4	57.2	43.6	42.6	46.5	42.0
Medical X-rays . . .	15.0	18.8	14.7	14.8	19.9	14.5	15.6	16.5	15.5
Dental X-rays	3.6	1.7	3.7	4.0	2.2	4.1	1.7	.7	1.8
Ultrasound	33.5	44.1	32.7	33.6	46.6	32.8	32.8	38.7	32.0
Nuclear medicine .	1.1	1.3	1.1	1.1	1.3	1.1	1.2	1.4	1.1
Shortwave . . . . .	.9	1.7	.9	.9	1.7	.9	1.7	1.5	1.7
Microwave . . . . .	.6	1.6	.6	.6	1.6	.6	1.5	1.5	1.5

¹ Figure does not meet standards of reliability or precision; that is, the relative standard error is 25 percent or more.

in table 2 range from a high of 19.9 percent for married mothers who had low birth weight infants to 14.5 percent for married mothers who had infants weighing 2,500 g or more.

Among women with pregnancies resulting in live births or stillbirths, the X-ray exposure rates were higher for white mothers than for mothers of other races. Teen age mothers of live-born infants in 1980 were more likely than mothers age 20 and older to be exposed to medical X-rays (table 4). Larger proportions of less educated women were exposed, although the differences were not statistically significant. For mothers of stillborn infants, the proportion exposed to medical X-rays was about 50 percent greater than that for mothers of live-born infants. Among mothers of stillborn infants (unlike mothers of live-born infants), women 20–24 years of age and women 30 years of age and older were more likely to have been exposed than teenagers. There was no clear pattern of exposure by years of education for mothers of stillborn infants.

In 1980, 15 percent of the mothers who gave birth to live infants were exposed to medical X-rays during pregnancy, compared with 22.5 percent in 1963 (see chart). Percentages of mothers exposed to medical X-rays in 1963 and 1980 are compared in the chart according to maternal age and race; reductions are evident for women of all age and race groups. In 1963, 21.8 percent of white mothers were exposed to medical X-rays, compared with 25.9 percent of mothers of other races. In 1980, these proportions had declined to 15.6 percent for white mothers and 12.4 percent for mothers of other

In 1980, 15 percent of the mothers of live-born infants were exposed to medical X-rays during pregnancy. The proportion of exposed mothers of stillborn infants was about 50 percent greater.

racers. Thus, among white mothers, the percent exposed declined by less than one-third, and among mothers of all other races, by one-half.

Dental X-rays. Information on exposure to dental X-rays was also collected in the 1980 NNS–NFMS (tables 2 and 3). An estimated 3.6 percent of mothers of live-born infants were exposed to dental X-rays during pregnancy. Among mothers of stillborn infants, 2.4 percent were exposed to dental X-rays. Differences in the percentages exposed by birth weight of their infants and by marital status may reflect the relative social and economic disadvantages associated with mothers of low birth weight infants (disproportionately nonwhite) and unmarried women (disproportionately under 20 years). Further analysis according to characteristics of the mother is hampered because of the relatively small number of dental X-rays.

Ultrasound exposure. The 1980 NNS–NFMS provide the first national estimates of exposure to ultra-

Table 4. Percentage of women exposed to medical X-rays by birth outcome and selected maternal characteristics, United States, 1980

Maternal characteristics	Live births		Stillbirths	
	Number	Percent exposed	Number	Percent exposed
Total	3,612,000	15.0	19,202	23.4
Race:				
White	2,939,000	15.6	14,462	24.9
All other	674,000	12.4	4,739	19.1
Black	562,000	12.1	4,253	19.1
Age:				
Under 20 years	562,000	18.0	2,992	19.0
20–24 years	1,226,000	14.7	5,986	24.8
25–29 years	1,107,000	14.6	5,189	21.4
30–34 years	561,000	13.3	3,191	24.9
35 years and over	156,000	14.3	1,845	29.2
Education:				
0–11 years	832,000	17.1	5,279	21.4
12 years	1,592,000	15.3	8,729	25.5
13–15 years	680,000	13.0	2,914	20.9
16 years or more	509,000	13.2	2,279	23.6

sound. In 1980 ultrasound was being used for about one-third of the mothers who gave birth to live infants (table 2). Ultrasound was more likely to be used for mothers who had low birth weight infants, and, as with medical X-rays, it was used most often for married women having low birth weight infants.

There are no significant differences by race in ultrasound exposure of mothers of live-born infants (table 5). The percentages of mothers exposed to ultrasound increased with age and additional years of education. Among mothers of stillborn infants, 55.5 percent of white mothers—and 47.2 percent of mothers of other races—were exposed to ultrasound (table 3). As with mothers of live-born infants, the percentages of mothers of stillborn infants exposed to ultrasound increased with age and education.

Comparison with electronic fetal monitoring (EFM). In addition to the radiation portions of questionnaires sent to all medical sources, hospitals were

asked whether electronic fetal monitoring (including doppler ultrasound) was used in the management of the pregnancy (see "Electronic Fetal Monitoring in Relation to Cesarean Section Delivery," also in this issue). There is only a weak association between doppler ultrasound used for fetal monitoring and the ultrasound procedures examined in this study; in addition, relatively few ultrasound procedures were reported to be used for monitoring during labor. These results lead us to conclude that ultrasound procedures are primarily not doppler ultrasound used for fetal monitoring. It is probable that the hospitals responding to the questionnaire did not consider monitoring during labor as an ultrasound procedure. In subsequent studies, the kinds of ultrasound procedures used will be specified in detail.

Nuclear medicine, shortwave, and microwave. Information on exposure through nuclear medicine, shortwave, and microwave treatments and examinations was also sought. Less than 3 percent of the

Percent of mothers exposed to medical X-rays during pregnancy by age of mother and race of mother: United States, 1963 and 1980

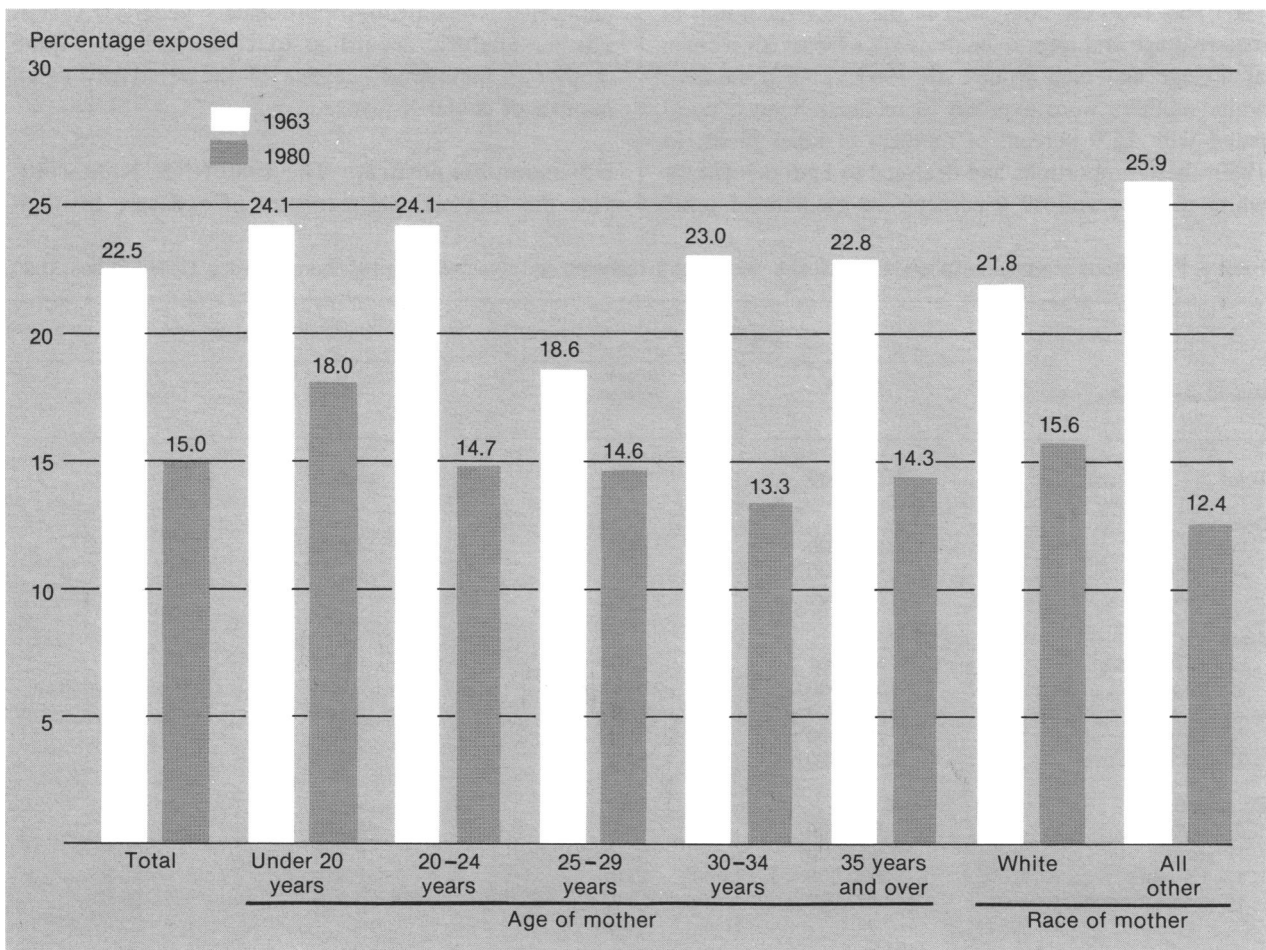


Table 5. Percentage of women exposed to ultrasound by birth outcome and selected maternal characteristics, United States, 1980

Maternal characteristics	Live births		Stillbirths	
	Number	Percent exposed	Number	Percent exposed
Total	3,612,000	33.5	19,202	53.4
Race:				
White	2,939,000	33.5	14,462	55.5
All other	674,000	33.3	4,739	47.2
Black	562,000	33.8	4,253	47.1
Age:				
Under 20 years	562,000	30.2	2,992	44.8
20-24 years	1,226,000	32.2	5,986	52.6
25-29 years	1,107,000	34.6	5,189	55.6
30-34 years	561,000	34.8	3,191	57.3
35 years and over	156,000	41.6	1,845	57.7
Education:				
0-11 years	832,000	31.2	5,279	47.0
12 years	1,592,000	32.6	8,729	54.4
13-15 years	680,000	35.8	2,914	57.4
16 years or more	509,000	36.7	2,279	59.7

women who had live-born and stillborn infants were exposed to shortwave or microwave radiation. As expected, the percentage exposed to nuclear medicine procedures was small (so small that estimates were unreliable). Differences by birth outcome, birth weight, and marital status were not significant.

Future Research

Future NCDRH research will focus in depth on radiation exposure by trimester of pregnancy, indications for use, primary area of body exposed, type of procedure, and type of examination. Subsequent research will also investigate maternal and infant health characteristics in relation to radiation exposure.

References

1. Stewart, A., and Barber, R.: Survey of childhood malignancies. *Public Health Rep* 77: 129-139, February 1962.
2. Stewart, A., and Kneale, G. W.: Changes in the cancer risk associated with obstetric radiography. *Lancet* 1: 104-107, Jan. 20, 1968.
3. Stewart, A.: Radiation dose effects in relation to obstetric x-rays and childhood cancers. *Lancet* 1: 1185-1188, June 6, 1970.
4. Stolzenberg, S. J., Torbet, C. A., Edmonds, P. D., and Taenzer, J. C.: Effects of ultrasound on the mouse exposed at different stages of gestation: acute studies. *Radiat Environ Biophys* 17: 245-270 (1980).
5. Stratmeyer, M. E., et al.: Growth and development of mice exposed in utero to ultrasound. *In* Symposium on Biological Effects and Characterization of Ultrasound Sources. DHEW

Publication (FDA) 78-8048. U.S. Government Printing Office, Washington, D.C., 1977.

6. Moore, R. Barrick, M., and Hamilton, P.: Effect of sonic radiation on growth and development [Abstract]. *Am J Epidemiol* 116: 571 (1982).
7. Lyons, E. A., Coggrave, M., and Brown, R. E.: Follow-up study in children exposed to ultrasound in utero: an analysis of height and weight in the first six years of life [Abstract]. *In* Proceedings of the 1980 Conference of the American Institute of Ultrasound in Medicine. p. 49, 1980.
8. Stark, C. R., Orleans, M., Haverkamp, A. D., and Murphy, J.: Effects of gestational ultrasound exposure on the outcome of pregnancy. *Am J Obstet Gynecol*. In press.
9. Scheidt, P. C., Stanley, F., and Bryla, D. A.: One year follow-up of infants exposed to ultrasound in utero. *Am J Obstet Gynecol* 131: 743-748 (1978).
10. National Center for Health Statistics: Volume of x-ray visits, United States, July 1960-June 1961; Series B, No. 38. PHS Publication No. 584-B38. U.S. Government Printing Office, Washington, D.C., 1962.
11. Gitlin, J. N., and Lawrence, P. S.: Population exposure to x-rays, United States, 1964. PHS Publication No. 1519. U.S. Government Printing Office, Washington, D.C., 1966.
12. National Center for Health Statistics: Volume of X-ray visits, United States, April-September, 1970, Series 10, No. 81, DHEW No. (HSM) 73-1507. U.S. Government Printing Office, Washington, D.C., April 1973.
13. Brown, M. L., Roney, P. L., Gitlin, J. N., and Moore, R. T.: X-ray experience during pregnancy. *JAMA* 199: 309-314, Jan. 30, 1967.
14. National Center for Health Statistics: Medical X-ray visits and examinations during pregnancy, United States, 1963; Series 22, No. 5. PHS Publication No. 1000. U.S. Government Printing Office, Washington, D.C., 1968.