Results of 4 years of followup in the Kauai Pregnancy Study indicate that rates obtained from an antenatal life table more nearly reflect the true magnitude of early fetal mortality than measures previously reported.

Probabilities of Fetal Mortality

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THE estimated probabilities of fetal mortality reported in this paper and the discussion of problems of obtaining and analyzing data on fetal losses in early pregnancy are based on a followup study of pregnancies on the island of Kauai during the 4-year period 1953–56 (*1*, *2*).

While this paper is concerned with measuring the risk of fetal mortality, the followup study of which it is a part uses a broad epidemiologic approach to the investigation of many conditions that may be associated with the qualitative as well as the quantitative outcome of pregnancy. It is hoped that our analyses, which are still in progress, and the studies of others engaged in field and laboratory investigations will throw additional light on the nature and relationships of the many factors which determine whether the outcome of pregnancy will be death of the conceptus, congenital defect, or healthy development.

When estimating the risk of loss for the successive stages of pregnancy, it is important to keep in mind that different methods of investigation are required for different periods of gestation. For the latter part of pregnancy, customary fetal death ratios, based on registered fetal deaths and live births, can be used with a good deal of confidence. For example, it was estimated that in 1956 in the Scandinavian countries 1,000 women whose pregnancies had progressed to the 28th week of gestation would have 17 fetal losses (*3*). For women in New York City reaching the same stage of pregnancy in 1958 the chances of fetal loss were 14 for the white and 19 for the nonwhite population, excluding fetal deaths of unknown length of gestation, according to a special tabulation prepared for this study by the U.S. National Office of Vital Statistics.

The farther we push back toward the beginning of antenatal life, however, the more limited knowledge becomes. Studies of loss and damage up to the first missed menstrual period are in the domain of embryologists using highly specialized laboratory methods. (This ovular period corresponds to the first 2 weeks of fetal life, from fertilization to about a week after implantation.) During the month after the first missed menses, the 4–7 week period of gestation, pregnancies can be recognized clinically. But it is unrealistic to assume that many women in a community will seek medical care this early in pregnancy. However, since some women will recognize a fetal loss during these early weeks, field studies such as the Kauai Pregnancy Study can add important information. From the eighth week of gestation on, more and more fetal losses come to the attention of physicians. Nevertheless, efforts to obtain reports prior to the 28th week of pregnancy have so far met with little success except in a few areas.

The Kauai Pregnancy Study (KPS) was designed to provide information about early pregnancies, from 4 weeks' gestation on, which is

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not ordinarily available for study, that is, reports of pregnancy from the women themselves as soon as they suspected they were pregnant. This enabled us to learn about more pregnancies and more early fetal losses than is possible through customary reports from physicians, hospitals, and registrars of vital statistics. Because of the followup nature of this study, losses which were known to have occurred in the various months of pregnancy could be related to well-defined groups of women known to be pregnant during each interval of gestation. This was accomplished by the life table method of analysis.

The Setting

The island of Kauai, with a population of about 30,000, lies 100 miles northwest of Honolulu. The main industries are growing and processing sugar cane and pineapples. While three-fourths of the population are classified as living in rural areas, one is immediately impressed with much of the island's distinctly suburban atmosphere. There are 10 to 15 resident physicians and 2 hospitals. Enrollment in plantation medical care and hospitalization plans is almost universal. The situation is as favorable as or better than for the rest of the United States for life expectancy at birth, proportion of women receiving prenatal care, and proportion of infants born in hospitals. Kauai's birth rate is similar to that of the white population in mainland communities, and its infant mortality rate is about 10 percent lower than for the white population of the United States and less than half the rate for nonwhites.

Of the women studied, 87 percent were born in Hawaii, about 5 percent in the Philippines, 5 percent in continental United States, and 2 percent in Japan; 38 percent were of Japanese, 21 percent of Filipino, and 17 percent of Hawaiian or part-Hawaiian origin. About two-thirds of the women had had pregnancies prior to the time of the study, the median age at first KPS pregnancy being 26 years. Almost two-thirds had only one pregnancy during the 4-year period of observation; 88 percent had no fetal deaths, 11 percent had one, and 1 percent had two or three.

Material

A unique aspect of KPS was the variety of records, most of which were prepared specifically for this study. While the information referred not only to the prenatal period and delivery but to the first 18 months of postnatal

Table 1. Outcome of 3,197 total pregnancies and of 3,083 pregnancies used in life table analysis, Kauai Pregnancy Study, 1953–56

Outcome	Total pregnancies	Used in life table analysis	Excluded from life table analysis	
			Number	Reason
All pregnancies	3, 197	3, 083	114	
Live births	2, 793	2, 777	16	
Single	2, 763	2, 748	15	Pregnancy reported after termination.
Twin	30	[1] 29	1	Do.
Fetal deaths	370	273	97	
Single:				
Ectopic pregnancy	16	16	0	
Hydatidiform mole	3	3	0	
Other	349	252	2	Therapeutic abortion.
			33	Pregnancy reported after termination.
			55	Pregnancy probably reported because of loss episode.
			7	Unknown gestational age at first report or at termination of pregnancy, or both.
Twin	2	[1] 2	0	
Unknown, pregnant woman moved	34	33	1	Unknown gestational age at first report and at termination of pregnancy.

[1] First born only; second born resulted in 30 live births and 1 fetal death.

life, material useful for this analysis was included on one or more of the following: pregnancy report cards mailed or brought to the KPS office by the pregnant woman, family member, friend, or study worker; prenatal records prepared by practicing physicians or copied from their records by office nurses or KPS workers; records of as many as three prenatal interviews by KPS staff; labor, delivery, and newborn records from hospitals; official certificates of fetal deaths, live births, and infant deaths; and autopsy reports. Cross-checking information included on more than one record turned up errors that would not have been caught had there been but one source of information.

One of our goals was to identify every pregnant woman on the island within a month after her first missed menses. But despite the energetic methods used to obtain early reports (*2*), some pregnancies must have terminated soon after the first missed period without our knowledge. Since it is inconceivable that all early pregnancies for an entire community will ever be known, it is necessary to learn what we can from those that are discovered, being as careful as possible that the group studied is representative in terms of the risk of loss.

Pregnancies first reported after termination were excluded, 16 ending in live births and 33 in fetal deaths (table 1). To guard against selection an additional 45 pregnancies were excluded because it is likely that these women came under followup because of symptoms associated with a fetal death; 10 more deaths were excluded because information was not adequate to determine the circumstances of the pregnancies. Also excluded were two therapeutic abor-

Table 2. Gestational age at termination of pregnancy, according to gestational age at first report, Kauai Pregnancy Study, 1953–56

Outcome of pregnancy and gestational age at first report (weeks)	Gestational age at termination of pregnancy or followup (weeks)										
	4–7	8–11	12–15	16–19	20–23	24–27	28–31	32–35	36–39	40+ [1]	Total
Total	32	73	79	30	30	18	37	86	1,086	1,612	3,083
Live birth	0	0	0	0	1	4	25	72	1,074	1,601	2,777
4–7	0	0	0	0	0	1	4	15	201	251	472
8–11		0	0	0	0	2	6	19	330	470	827
12–15			0	0	0	0	3	10	200	328	541
16–19				0	0	1	2	8	125	189	325
20–23					1	0	5	7	91	141	245
24–27						0	4	5	63	97	169
28–31							1	7	30	55	93
32–35								1	23	42	66
36–39									11	28	39
Fetal death	32	72	77	28	20	8	8	8	9	11	273
4–7	32	37	27	3	4	2	1	3	1	3	113
8–11		35	38	15	6	2	1	2	3	2	104
12–15			12	8	7	2	4	1	3	3	40
16–19				2	3	2	1	0	0	1	9
20–23					0	0	0	1	0	2	3
24–27						0	0	0	0	0	0
28–31							1	1	1	0	3
32–35								0	0	0	0
36–39									1	0	1
Unknown [2]	0	1	2	2	9	6	4	6	3	0	33
4–7	0	1	2	2	1	1	0	0	0	0	7
8–11		0	0	0	5	3	2	0	0	0	10
12–15			0	0	1	2	1	0	0	0	4
16–19				0	2	0	0	0	1	0	3
20–23					0	0	0	0	0	0	0
24–27						0	1	5	0	0	6
28–31							0	1	1	0	2
32–35								0	1	0	1
36–39									0	0	0

[1] Includes 35 live births terminating at 45–47 weeks' gestation; no fetal death occurred after 43 weeks' gestation.
[2] Moved while pregnant.

tions and eight pregnancies for which gestational age at first report or at termination of pregnancy, or both, were unknown.

Eighty percent of the pregnancies were under followup before the 20th week of gestation, 69 percent before the 16th week, and 50 percent as early as the 12th week, including 19 percent first reported between 4 and 8 weeks' gestation. Detailed information concerning time of first report and end of followup is shown in table 2 for fetal deaths, live births, and women who moved before pregnancy ended.

Fetal Deaths

Registered. Fifty-five percent of the fetal deaths in the study, 150 out of a total of 273, were registered (table 3). Of losses recorded in physicians' records, the percentage registered increased from 43 percent for those ending 4–7 weeks from the last menstrual period (LMP) to 86 percent for pregnancies ending after 23 completed weeks.

Known to physicians but not registered. For another 62 fetal deaths (23 percent) records of a physician or a hospital indicated that a fetal death had occurred or that a pregnancy had been diagnosed with no other explanation of the initial findings. In some instances the expelled conceptus was brought to the physician and pregnancy was confirmed; in others, the woman's description of her early loss episode was the basis for his diagnosis.

Other. The remaining 61 fetal deaths (22 percent) were not recorded in physicians' records. These losses, like the others studied, occurred to women whose pregnancies were reported to KPS prior to termination and, to the best of our knowledge, were not reported because of an imminent loss. In some instances the pregnant woman had consulted her physician, but he could not make or did not record a diagnosis of pregnancy, and when she made her next visit she was no longer pregnant. Others did not seek medical attention but reported their losses, as they had their preg-

Table 3. Fetal deaths, by gestational age, Kauai Pregnancy Study, 1953–56

Gestational age at fetal death (weeks)	All fetal deaths		Diagnosed by physician [1]								Total diagnosed by physicians		Not diagnosed by physician [5]
			Hospital delivery [2]		Hospitalized after delivery		Not hospitalized						
							Fetus seen by physician or others [3]		Other [4] and not documented				
	Total	Registered	Total	Registered	Total	Registered	Total	Registered	Total	Registered	Total	Registered	
Number	273	150	123	115	19	18	16	11	54	6	212	150	61
Percent	100.0	54.9	45.0	42.1	7.0	6.6	5.9	4.0	19.8	2.2	77.6	54.9	22.3
4–7	32	9	11	8	0	0	1	0	9	1	21	9	11
8–11	72	33	26	23	7	6	5	2	13	2	51	33	21
12–15	77	43	27	27	8	8	7	6	19	2	61	43	16
16–19	28	14	11	10	2	2	1	1	5	1	19	14	9
20–23	20	14	11	11	2	2	1	1	3		17	14	3
24–27	8	3	3	2			1	1	4		8	3	0
28–31	8	7	7	7					0		7	7	1
32–35	8	7	7	7					1		8	7	
36–39	9	9	9	9							9	9	
40+ [6]	11	11	11	11							11	11	

[1] Pregnancy or fetal death or both diagnosed by physician.

[2] Includes 16 ectopic pregnancies: 10 at 4–7 weeks', 5 at 8–11 weeks', 1 at 12–15 weeks' gestation; 11 registered, 5 unregistered.

[3] Includes positive pathological findings and positive pregnancy tests.

[4] Based on clinical findings, woman's description of loss, or both.

[5] Based on woman's description of loss.

[6] See table 2, footnote 1.

nancies, directly to the study staff. These women were classified as having fetal losses on the basis of signs and symptoms they reported.

It should be kept in mind that, because of the earliness of most such losses, the evidence given by the women directly to the study staff is little if any different from that recorded by physicians and used as the basis for their diagnosis of early loss. For example, 9 of the 20 losses at 4–7 weeks that were based on the women's reported symptoms were reported to us via physicians' records and 11 were reported directly to the study staff. For two others there was clinical evidence of loss. The 10 ectopic pregnancies during this interval, of course, were learned about through the attending physicians. Generally, the women described a period of amenorrhea unusual in terms of their own menstrual histories, followed by abnormal vaginal bleeding of a type consistent with the period of gestation and for which there was no explanation.

Not Pregnant

Fifty-one pregnancy reports were judged to have been in error. Included were periods of amenorrhea later diagnosed as related to the menopause or to hormonal dysfunction. There were also instances of uterine tumor and pseudocyesis, as well as reports based on pure supposition; for example, a report by a neighbor of the pregnancy of a woman who had had eight pregnancies in quick succession, on the assumption that it was time for her to be pregnant again.

Method

We followed the customary practice of measuring the period of gestation from the first day of the last menstrual period prior to the beginning of pregnancy; the LMP used was based on a review of all available records for each pregnancy. Termination of pregnancy was taken as the date of expulsion of the conceptus, unless the medical attendant gave an earlier date; when no recognizable product of conception was involved, the beginning of abnormal bleeding was taken as the estimated date of termination of pregnancy. Time intervals between LMP and first report of pregnancy and the end of pregnancy were calculated as described in a previous paper (*2*); in brief, because so many different intervals were studied, computations were simplified by converting all dates to weeks. The beginning of followup for each pregnancy was the week of the first report of pregnancy directly to KPS or through a Kauai physician.

An ever-present problem is the differentiation between fetal deaths and live births which, strictly speaking, should be classified as early neonatal deaths by virtue of the fact that the conceptus was observed to show some evidence of life, such as beating of the heart, pulsation of the umbilical cord, or movement of voluntary muscles. Although Kauai physicians are aware of and responsive to reporting requirements of Hawaii, which emphasize these distinctions in definition, some errors undoubtedly were made, both in hospitalized and nonhospitalized cases. Potter and Shapiro (*4*) in 1954 reported considerable variation in reporting standards in mainland hospitals, including those which are the major teaching units of medical schools.

Fetal Death Ratios and Life Table Rates

Reported fetal losses occurring in the early months of gestation, when ratioed to total live births or live births plus reported fetal deaths (fetal death ratios), fall far short of measuring the risk of fetal loss. However, with data from followup studies such as KPS, fetal death rates can be calculated. Reports of two followup studies of pregnancy and congenital defects, one in New York City (*5*) and one in England (*6*), allow only the calculation of fetal death ratios; data collected in the former are being analyzed by the life table method (*7*).

The differences between fetal death ratios and estimated probabilities of loss (fetal death rates) are illustrated with KPS data in table 4. Measure A is the number of fetal deaths during each month of pregnancy related to all births. Measure B relates the same number of deaths to total births but refines the "exposed to risk" group by removing those terminating earlier. The life table probabilities of loss, measure C, are based on women under observation during each interval of study.

Measures A and B, fetal death ratios, are

almost identical; the reduction of the denominator for the latter has little effect until the end of pregnancy. These ratios are similar to the rates after about 24 weeks of gestation; this is expected since most pregnancies were under observation during the latter months. The greatest disparity is in the first interval studied (4–7 weeks from LMP), for which estimated probabilities of loss refer only to pregnancies under observation at that time.

Life Table Analysis

Cohort analysis for the antenatal period of life in general follows well-known life table methodology. Because this is the first time, to our knowledge, that the analysis of followup data for an entire community has been reported in this fashion, a few comments may be in order.

KPS women included in the cohort have a common experience: all were reported to have had their LMP in the 4 years 1953–56.

KPS was designed to follow pregnancies from the time the women themselves could be aware they were pregnant—from the first missed menstrual period. The start of followup, therefore, was taken as the beginning of the fourth week from LMP. Because all pregnancies in the cohort were not reported by the fourth week, the actual period of observation for some began after this time, a situation which introduced problems not usually encountered in medical followup studies.

The following comments refer to life table functions calculated from KPS data, an example being shown in table 5. In the course of the analysis various subgroups of the total

Table 4. Comparison of two customary fetal death ratios, and estimated probability of fetal loss, by gestational age, Kauai Pregnancy Study, 1953–56

Gestational age at termination of pregnancy (weeks)	Live births		Fetal deaths			Denominators of measures			Measures of fetal loss		
				Excluded		For customary fetal death ratios		For life table	Fetal death ratios		Estimated probability of fetal death per 1,000 exposed to risk [1] [6]
	Used in life table analysis [1]	Excluded [2]	Used in life table analysis [1]	Reported after termination of pregnancy [3]	Probably selected [4]	Total pregnancies [5] (A)	Total pregnancies not terminated (B)	Exposed to risk [1] [6] (C)	Deaths per 1,000 total pregnancies [5] (A)	Deaths per 1,000 pregnancies not terminated (B)	(C)
All pregnancies	2,777	16	273	42	55	3,163	3,163	-------	117.0	117.0	237.2
4–7	0	0	32	12	9	3,163	3,156	296.0	16.8	16.8	108.1
8–11	0	0	72	14	24	3,163	3,103	1,030.0	34.8	35.4	69.9
12–15	0	0	77	7	18	3,163	2,993	1,719.5	32.2	34.1	44.8
16–19	0	0	28	2	3	3,163	2,891	2,101.5	10.4	11.4	13.3
20–23	1	0	20	0	0	3,163	2,858	2,360.5	6.3	7.0	8.5
24–27	4	0	8	0	1	3,163	2,837	2,543.5	2.8	3.2	3.2
28–31	25	0	8	0	0	3,163	2,824	2,663.0	2.5	2.8	3.0
32–35	72	3	8	0	0	3,163	2,791	2,707.5	2.5	2.9	3.0
36–39	1,074	4	9	0	0	3,163	2,708	2,676.5	2.8	3.3	3.4
40+ [7]	1,601	9	11	0	0	3,163	1,621	1,612.0	3.5	6.8	6.8
Unknown	0	0	0	7	0	3,163	-------	-------	2.2	-------	-------

[1] See table 5.
[2] First reported at termination of pregnancy.
[3] Includes 2 therapeutic abortions, 1 at 4–7 weeks' and 1 at 12–15 weeks' gestation.
[4] Pregnancies excluded because symptoms associated with fetal death probably led to their being reported.
[5] Live births plus fetal deaths.
[6] Estimated effective number of pregnancies at beginning of interval exposed to risk of termination in interval.
[7] See table 2, footnote 1.

cohort were analyzed; the sample work table refers to all pregnancies.

In column 2 the number of pregnancies at the beginning of each interval (l_x) is obtained as follows:

$$l_{x+1}=l_x+n_x-f_x-b_x-m_x$$

where n stands for the number of women first reported pregnant in the interval x to $x+1$, f_x and b_x for the number of fetal deaths and live births respectively, and m_x for the number of pregnant women who moved in the interval x to $x+1$. Each interval represents 1 lunar month or 4 weeks.

In columns 8–10 the estimated probability of a fetal death or of a live birth during an interval, or of a woman still being pregnant at the end of an interval, is the crude probability that a woman, pregnant at time x, will experience the specified event in the interval x to $x+1$, in the presence of the other two possible events.

Women first reported pregnant in a specified interval from x to $x+1$ are assumed to have been under observation one-half of the interval on the average. A 10 percent systematic sample of live births and of fetal deaths reported in the 4–7 week period indicates that this assumption is reasonable. A similar assumption is made for those who moved.

Estimated probabilities were calculated as follows:

Fetal death:

$$\hat{q}_x=\frac{f_x-\frac{1}{2}\hat{q}_x n_x+\frac{1}{2}\hat{q}_x m_x}{l_x}=\frac{f_x}{l_x+\frac{1}{2}n_x-\frac{1}{2}m_x}=\frac{\text{column 4}}{\text{column 7}}$$

Live birth:

$$\hat{r}_x=\frac{b_x-\frac{1}{2}\hat{r}_x n_x+\frac{1}{2}\hat{r}_x m_x}{l_x}=\frac{b_x}{l_x+\frac{1}{2}n_x-\frac{1}{2}m_x}=\frac{\text{column 5}}{\text{column 7}}$$

Still pregnant:

$$\hat{p}_x=1-\hat{q}_x-\hat{r}_x$$

The denominator (d_x) used in calculating these probabilities is given in column 7.

Table 5. Sample worktable for calculation [1] of antenatal life table function, Kauai Pregnancy Study, 1953–56

Period of gestation between two exact gestational ages stated in weeks	Number pregnancies in interval					Estimated number of pregnancies exposed to risk [2]	Estimated probability of outcome per 1,000 pregnancies						
			Ending in—				During interval			From 4 weeks through specified interval			Fetal death from gestational age x to end of pregnancy
	At beginning	First reported	Fetal death	Live birth	Moved		Fetal death	Live birth	Still pregnant	Fetal death	Live birth	Still pregnant	
(1)	(2)	(3)	(4)	5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
x to $x+1$	l_x	n_x	f_x	b_x	m_x	d_x	$\hat{q}_x$	$\hat{r}_x$	$\hat{p}_x$	$\hat{q}_{1x}$	$\hat{r}_{1x}$	$\hat{p}_{1x}$	$\hat{q}_{x10}$
4–8	0	592	32	0	0	296. 0	108. 11	0. 00	891. 89	108. 11	0. 00	891. 89	237. 25
8–12	560	941	72	0	1	1, 030. 0	69. 90	. 00	930. 10	170. 45	. 00	829. 55	144. 79
12–16	1, 428	585	77	0	2	1, 719. 5	44. 78	. 00	955. 22	207. 60	. 00	792. 40	80. 52
16–20	1, 934	337	28	0	2	2, 101. 5	13. 32	. 00	986. 68	218. 15	. 00	781. 85	37. 42
20–24	2, 241	248	20	1	9	2, 360. 5	8. 47	. 42	991. 11	224. 77	. 33	774. 90	24. 43
24–28	2, 459	175	8	4	6	2, 543. 5	3. 15	1. 57	995. 28	227. 21	1. 55	771. 24	16. 11
28–32	2, 616	98	8	25	4	2, 663. 0	3. 00	9. 39	987. 61	229. 52	8. 79	761. 69	13. 02
32–36	2, 677	67	8	72	6	2, 707. 5	2. 95	26. 59	970. 46	231. 77	29. 04	739. 19	10. 15
36–40	2, 658	40	9	1, 074	3	2, 676. 5	3. 36	401. 27	595. 37	234. 25	325. 66	440. 09	7. 42
40+[3]	1, 612	0	11	1, 601	0	1, 612. 0	6. 82	993. 18	. 00	237. 25	762. 75	. 00	6. 82

[1] See text for explanation.

[2] Estimated effective number of pregnancies at beginning of interval exposed to risk of termination of pregnancy in interval.

[3] See table 2, footnote 1.

The one maternal death is not shown as a withdrawal since a fetal death had already occurred from independent causes. There were no withdrawals analogous to "withdrawn alive at end of study," a group encountered in some followup studies.

For women pregnant at 4 weeks' gestation (cols. 11–13), the estimated probability of a fetal death, of a live birth, or of still being pregnant from 4 weeks' gestation through interval x are given below:

Still pregnant:

$$\hat{p}_{1x}=\hat{p}_1\hat{p}_2 \ldots \hat{p}_x$$

Fetal death:

$$\hat{q}_{1x}=\hat{q}_1+\hat{p}_1\hat{q}_2+\hat{p}_1\hat{p}_2\hat{q}_3+ \ldots +\hat{p}_1 \ldots \hat{p}_{x-1}\hat{q}_x$$

$$=\sum_{1}^{x} \hat{p}_{x-1}\hat{q}_x, \text{ with } x=1, 2, \ldots, 10, \text{ and } \hat{p}_0=1$$

Live birth:

$$\hat{r}_{1x}=1-\hat{p}_{1x}-\hat{q}_{1x}$$

For women pregnant at time x (col. 14), the estimated probability of a fetal death from time x to the end of pregnancy is:

$$\hat{q}_{x10}=\hat{q}_x+\hat{p}_x\hat{q}_{x+1}+\hat{p}_x\hat{p}_{x+1}\hat{q}_{x+2}+ \ldots +\hat{p}_x \ldots \hat{p}_9\hat{q}_{10}$$

$$=\sum_{x}^{10} \hat{p}_{x-1}\hat{q}_x, \text{ with } x=1, 2, \ldots, 10, \text{ and } \hat{p}_0=1$$

A current antenatal life table, based on a radix of 1,000 women pregnant at 4 weeks' gestation and on the estimated probabilities of fetal death and of live birth derived in table 5, is shown in table 6.

Findings and Discussion

As shown in figure 1 and table 5, column 8, estimated probabilities of fetal death for monthly gestational periods form a decreasing curve from a high point of 108 per 1,000 during 4–7 weeks of gestation. This is followed by a rate of 70 for women pregnant from 8–11

Table 6. Antenatal life table, Kauai Pregnancy Study, 1953–56

Period of gestation between two exact gestational ages stated in weeks	Rate per 1,000		Of 1,000 pregnant at 4 weeks			Number of months of followup for cohort		Average number of lunar months of pregnancy after x for women pregnant at exact gestational age x
	Between x and $x+1$, among 1,000 pregnant at x, the number of—		Number still pregnant at gestational age x	Between x and $x+1$, number of—		Between x and $x+1$	From x on until all have delivered	
	Fetal deaths	Live births		Fetal deaths	Live births			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
x to $x+1$	$\hat{q}_x$	$\hat{r}_x$	$\hat{l}_x$[1]	$\hat{f}_x$	$\hat{b}_x$	$\hat{L}_x$[2]	$\hat{T}_x$[3]	δ[4] e_x
4–8	108. 11	0. 00	1, 000. 00	108. 11	0. 00	945. 94	7, 282. 80	7. 28
8–12	69. 90	. 00	891. 89	62. 34	. 00	860. 72	6, 336. 86	7. 10
12–16	44. 78	. 00	829. 55	37. 15	. 00	810. 98	5, 476. 14	6. 60
16–20	13. 32	. 00	792. 40	10. 55	. 00	787. 12	4, 665. 16	5. 89
20–24	8. 47	. 42	781. 85	6. 62	. 33	778. 38	3, 878. 04	4. 96
24–28	3. 15	1. 57	774. 90	2. 44	1. 22	773. 07	3, 099. 66	4. 00
28–32	3. 00	9. 39	771. 24	2. 31	7. 24	766. 46	2, 326. 59	3. 02
32–36	2. 95	26. 59	761. 69	2. 25	20. 25	750. 44	1, 560. 13	2. 05
36–40	3. 36	401. 27	739. 19	2. 48	296. 61	589. 64	809. 69	1. 10
40+[5]	6. 82	993. 18	440. 10	3. 00	437. 10	220. 05	220. 05	. 50

[1] $\hat{l}_{x+1}=\hat{l}_x-\hat{f}_x-\hat{b}_x$

[2] $\hat{L}_x=\frac{1}{2}(\hat{l}_x+\hat{l}_{x+1})$

[3] $\hat{T}_x=\sum_{x}^{10} \hat{L}_x$, with $x=1, 2, \ldots, 10$

[4] $\delta e_x=\frac{\hat{T}_x}{\hat{l}_x}$

[5] See table 2, footnote 1.

Figure 1. Estimated probability of fetal death per 1,000 pregnancies, Kauai Pregnancy Study, 1953–56, and conventional fetal death ratio per 1,000 total pregnancies, Kauai Pregnancy Study and white and nonwhite population of New York City in 1958, by gestational age

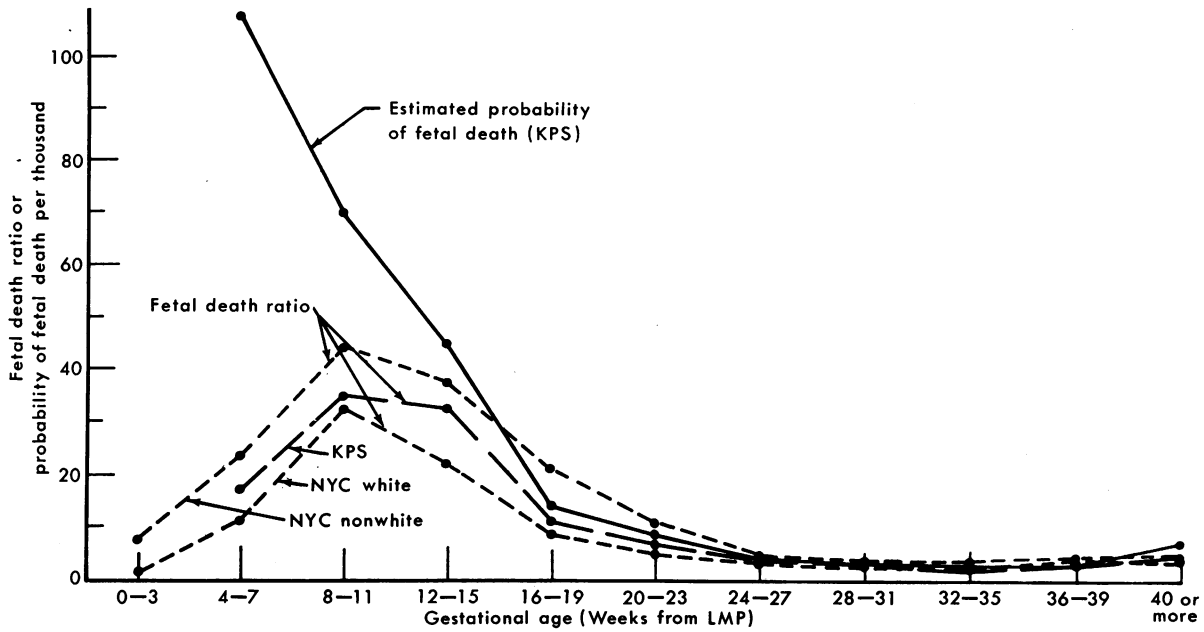


Table 7. Estimated probability of fetal death per 1,000 pregnancies,[1] by gestational age and earliness of first report, and probability of eventual fetal death for women still pregnant at beginning of specified gestational age interval, Kauai Pregnancy Study, 1953–56

Gestational age (weeks)	During 4-week interval							From beginning of interval to end of pregnancy				
	Total cohort			Gestational age at first report [2]					Gestational age at first report [2]			
	All pregnancies	Reported during interval	Pregnant at beginning of interval	4–7	8–11	12–15	16+	All pregnancies	4–7	8–11	12–15	16+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
4–7	108. 11	108. 11	-------	108. 11	-------	-------	-------	237. 25	237. 65	-------	-------	------
8–11	69. 90	74. 39	66. 13	66. 13	74. 39	-------	-------	144. 79	145. 24	145. 00	-------	------
12–15	44. 78	41. 03	45. 55	51. 82	41. 94	41. 03	-------	80. 52	84. 71	76. 29	88. 04	------
16–19	13. 32	11. 87	13. 45	6. 10	17. 28	13. 96	11. 87	37. 42	34. 69	35. 85	49. 02	31. 09
20–23	8. 47	. 00	8. 94	8. 21	7. 05	12. 40	6. 56	24. 43	28. 77	18. 90	35. 56	19. 45
24–27	3. 15	[3]. 00	3. 26	4. 15	2. 38	3. 60	3. 01	16. 11	20. 74	11. 94	23. 45	13. 02
28–31	3. 00	20. 41	2. 68	2. 09	1. 20	7. 24	2. 51	13. 02	16. 70	9. 61	19. 92	10. 06
32–35	2. 95	[3]. 00	2. 99	6. 33	2. 42	1. 83	2. 32	10. 15	14. 77	8. 48	12. 84	7. 69
36–39	3. 36	[3] 50. 00	3. 01	2. 19	3. 73	5. 62	2. 27	7. 42	8. 77	6. 22	11. 24	5. 56
40+ [4]	6. 82	[3]. 00	6. 82	11. 81	4. 24	9. 06	5. 41	6. 82	11. 81	4. 24	9. 06	5. 41

[1] From calculations similar to those used in table 5, columns 8 and 14, and described in text.
[2] Weeks from last menstrual period.
[3] Based on less than 100 months of followup.
[4] See table 2, footnote 1.

weeks and 45 for those observed during 12–15 weeks' gestation. Rates continue to decline as pregnancy progresses with a slight upswing for the last interval. The last rate is based on fetal deaths occurring no later than the 43d week of gestation.

Based upon monthly estimated probabilities of fetal loss, 237 of each 1,000 pregnancies, about 24 percent, ended in loss of the conceptus; this excludes the first 4 weeks of gestation not covered in studies of this kind. This measure of the total fetal death rate is twice as high as the ratio of 117 based on all live births and fetal deaths. In fact, the estimated probability of loss during 4–11 weeks alone is 170 per 1,000. Excluding the 4–7 week interval with the highest estimated rate, the estimate of eventual loss for women pregnant at 8 weeks is still 145 per 1,000. Other estimates of interest are shown in the antenatal life table. For example, of 1,000 women pregnant at 4 weeks, about a quarter will no longer be pregnant at 32 weeks' gestation.

In order to better understand the meaning of our estimates of loss, we examined some laboratory investigations on human ova and the work of several investigators of prenatal loss in mammals other than man (*8–11*). Although there is no completely satisfactory estimate of total prenatal mortality from fertilization to parturition in any species of mammal, each of these investigators presents evidence supporting a peak rate of loss around the time of implantation. From an intensive study of a small group of fertilized human ova, Hertig and associates (*8*) estimated a loss of some 40 percent before and during implantation.

The earliest losses we were able to observe probably represent a point on the downward slope of a loss curve which was highest 10–14 days earlier. Although we have no comparable data with which to compare our estimate of 24 percent eventual loss, it is of interest to note that about 30 percent of the implanted ova studied by Hertig and associates eventually were aborted. Our estimate is also in line with speculations made by Erhardt in the early 1950's, based on fetal death ratios in New York City (*12*).

Figure 2. Estimated probability of fetal death per 1,000 pregnancies for subcohorts of pregnancies first reported 4–7, 8–11, 12–15, and 16 weeks or more from last menstrual period, by gestational age, Kauai Pregnancy Study, 1953–56

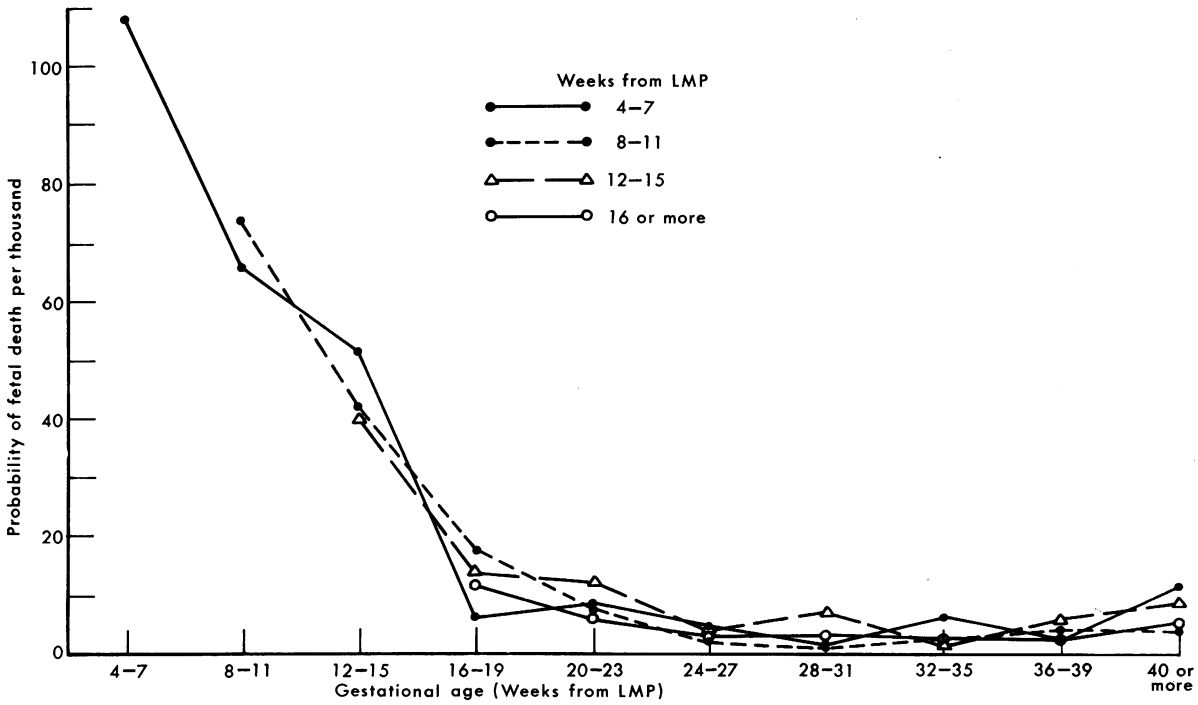
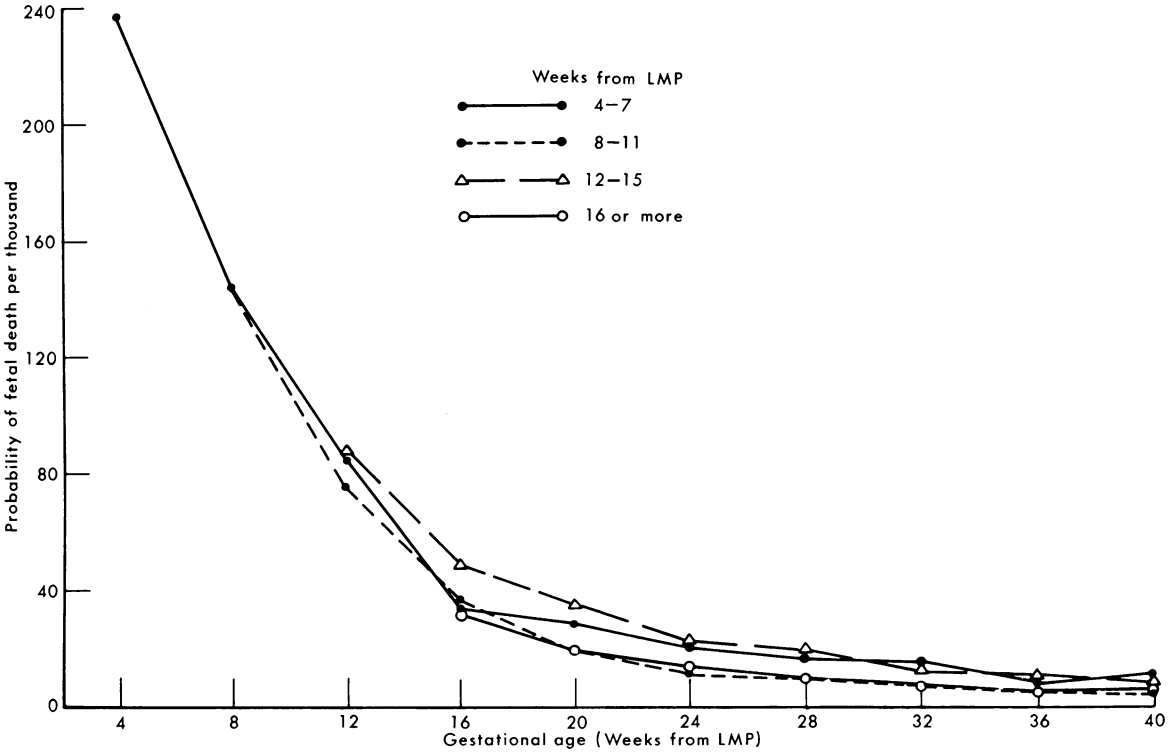


Figure 3. Estimated probability of eventual fetal death per 1,000 pregnancies for women still pregnant at specified gestational age, for subcohorts of pregnancies first reported 4–7, 8–11, 12–15, and 16 weeks or more from last menstrual period, Kauai Pregnancy Study, 1953–56



Kauai's high fetal loss rate might suggest that we are dealing with a particularly high-risk population. Evidence indicates quite the contrary. As was mentioned before, its infant mortality rate is even lower than for the white population of continental United States and less than half the rate for the nonwhite population. Also, fetal death ratios there, based on registered deaths of at least 20 weeks' gestation, are similarly low.

Although the estimated probabilities of fetal loss seem reasonable, we would be remiss if we did not attempt to determine whether pregnancies under observation during the early weeks of pregnancy were selective in terms of risk of fetal death. As will be recalled, 55 fetal deaths were excluded from the study in order to minimize this kind of selection. If the remaining pregnancies were not selected because of symptoms, for each gestational period the rate of loss based on those first reported in the interval (n_x) should be of approximately the same magnitude as the rate based on those reported in a previous interval (l_x). Such comparisons can be made beginning with the eighth week of gestation. As seen in table 7, for intervals of particular interest under 24 weeks, only for the 8–11 week period is the rate higher when based on pregnancies reported in the interval. This slight difference, if real, would be consistent with some selection although there appears to be none for the other intervals.

The above comparisons do not help in the assessment of selectivity for pregnancies reported at 4–7 weeks since the experience of this group is the sole basis for rates for this month of pregnancy. It is possible, however, to follow this group to termination of pregnancy and compare its general loss experience with pregnancies reported later. Monthly rates for four subcohorts based on earliness of report are compared in table 7 and figure 2. In addition, probabilities of eventual loss for women in each group who are still pregnant at specified weeks of gestation are shown in figure 3. From the 12th week on, pregnancies reported 4–7 or 8–11

Table 8. Selected characteristics of pregnancies, by earliness of first report of pregnancy, Kauai Pregnancy Study, 1953–56

Characteristic	First report of pregnancy [1]				
	4–7	8–11	12–15	16+	Total
	Percent				
Reported fetal deaths among all previous pregnancies:					
20 or more weeks' gestation	2.4	2.5	3.0	2.4	2.5
Less than 20 weeks' gestation	14.2	12.0	10.2	8.3	10.9
Reported fetal deaths among immediately preceding pregnancies:					
20 or more weeks' gestation	.5	1.3	1.2	1.2	1.1
Less than 20 weeks' gestation	15.9	12.3	10.2	7.9	11.3
Both husband and wife:					
Filipino	15.9	17.9	20.3	19.0	18.3
Hawaiian or part-Hawaiian	18.8	19.0	20.5	35.0	24.2
Other mixture	12.3	13.5	16.2	15.6	14.4
Japanese	38.4	36.7	31.5	22.6	31.6
Portuguese	7.5	6.0	6.0	4.4	5.8
Other Caucasian	3.2	4.8	2.6	2.2	3.3
Husband not laborer	75.7	79.4	75.2	69.5	74.9
Not first pregnancy	79.8	82.9	78.8	73.7	78.6
Households with 2 or 3 persons	35.6	33.5	31.8	27.4	31.7
Woman married at time of delivery	98.5	98.6	97.4	90.4	95.8
	Years				
Median age of wife	27.1	27.0	26.3	24.9	26.3
Median interval from last pregnancy	1.3	1.3	1.6	.9	1.2

[1] Weeks from last menstrual period.

weeks from LMP do not have consistently higher rates of loss. It seems reasonable to conclude that if there is any self-selection involved, the effect in terms of increased rates is limited to losses before 12 weeks' gestation.

Since the only rates we could calculate for the 4–7 weeks' period must be based on those pregnancies reported in that interval, we examined these pregnancies as well as those reported at 8–11 weeks to see whether they had characteristics which might be associated with higher than usual fetal death rates during the first weeks studied. One characteristic might be previous early losses (*1*). As seen in table 8, this would appear to be the case. However, we doubt the validity of these reported differences. In the first place, Filipinos, Hawaiians, and part-Hawaiians are under-represented among the early reporters; yet it has been found for all of Hawaii as well as in this study that these ethnic groups have relatively high proportions of total births ending in early fetal deaths. Furthermore, early reporters in this series appear to have characteristics ordinarily associated with low risk of fetal death. They were of a higher socioeconomic status as indicated by occupation of husband, family size was smaller, the interval from last pregnancy was somewhat longer, and a larger percentage were married at delivery. Taken all together, we believe that the women whose pregnancies were reported early were not only more conscientious about reporting current pregnancies early but also in recalling and reporting previous early fetal deaths. It would appear, therefore, that if anything our early reporters more resembled low-risk than high-risk women.

As was pointed out previously, all fetal losses occurring in a community cannot be identified, even excluding the first 4 weeks of gestation. Therefore, investigators are faced with the problem of analyzing those which are discovered. The rates obtained in this study appear to be reasonable. And in spite of the possibility of some residual selection, we believe these rates more nearly reflect the true magnitude of

early fetal mortality than measures previously reported. We will await with great interest the results of similar followup studies.

Summary

The data analyzed were collected in the Kauai Pregnancy Study, a communitywide followup study on the island of Kauai, Hawaii. The island's population of some 30,000 differs from mainland communities in certain respects, but its health indices compare favorably with those of the white population of other States.

Fifty percent of the pregnancies reported in the study were identified and under followup before the 12th week of gestation.

Included in the study are fetal deaths occurring from 4 weeks' gestation to the end of pregnancy. Eight out of 10 pregnancies were diagnosed by physicians. The remainder were losses reported by the women involved—information not included in data supplied by physicians, hospitals, or registrars of vital statistics.

Estimates of the probability of fetal loss (fetal death rates) are based on losses occurring to women known to be pregnant during successive stages of pregnancy. Because periods of observation varied from woman to woman, the life table method of analysis was used.

Based on estimated rates of loss during successive months, 24 percent of pregnancies reaching 4 weeks' gestation ended in loss of the conceptus.

Estimated fetal death rates by gestational period were found to form a decreasing curve from a high of 108 losses per 1,000 women under observation for the 4–7 weeks' period.

While similar rates based on pregnancies under observation are not available from other areas for comparison, the magnitude of the rates appears to be reasonable and consistent with previous estimates. In spite of the possibility of some residual selection, we believe these rates more nearly reflect the true magnitude of early fetal mortality than measures previously reported.

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Medical Care Prices

Medical care prices reached record-high levels in the second quarter of 1962, according to Bureau of Labor Statistics price indexes appearing in the September 1962 issue of *Health, Education, and Welfare Indicators.*

By June 1962, medical care prices had risen an average of 14.4 percent above the 1957–59 base of 100. The price of hospitalization insurance increased the most, with a rise of 36.6 percent. The hospital daily service charge increased 29 percent, physicians' fees 12 percent, dentists' fees 8 percent, but prices of selected prescriptions and drugs were down to the 1957–59 level.

The June 1962 Consumer Price Index shows an average price increase of 5.3 percent for 300 goods and services, including medical care, in reference to the 1957–59 base. The medical care component had risen 14.4 percent (a 0.3 percent increase since the previous month). The average increase since June 1961 was 1.2 percent for all goods and services and 2.8 percent for medical care alone.

The 153-page supplemental 1962 *Health, Education, and Welfare Trends*, now available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C., at $1, contains health and vital statistics and data on manpower, facilities, prices, and expenditures related to health and medical care.