Further Observations on the Relationship of Maternal ABO and Rh Types to Fetal Death

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It has long been recognized that there is negative selection against offspring who carry ABO or Rh antigens absent in their mothers, so-called incompatibles. Numerous retrospective studies have provided evidence based on various kinds of data: the relative frequencies of parental types; the number and blood-group distribution of offspring, especially from different parental types, as such, or in terms of mother-offspring combinations and/or father-offspring combinations; fertile matings by blood type, including reciprocal matings; the blood groups of sterile couples and the parents of affected children; as well as maternal blood types in relation to offspring birth weight and fetal loss. In addition to the investigations cited elsewhere (Cohen, 1960), there are other pertinent reports (Allan, 1953; Bennett and Brandt, 1954; Reepmaker *et al.*, 1954; Bennett and Walker, 1956; Munk-Andersen, 1958; Osborne and De George, 1957; Davidsohn *et al.*, 1958; Levine, 1959; Reed and Ahronheim, 1959; Behrman *et al.*, 1960; Robinson *et al.*, 1960), some more recent (Andersen *et al.*, 1961; Chung and Morton, 1961; Levene and Rosenfield, 1961; Bresler, 1964; Donohue and Wake, 1964; Reed *et al.*, 1964; Knox, 1965*a*, 1965*b;* Morton *et al.*, 1966; Peritz, 1967).

In spite of voluminous literature on this subject, however, the previous studies concerned specifically with fetal wastage were few and confined to relatively small samples or selected aspects of the problem (Levine and Stetson, 1939; Levine, 1943; McNeil *et al.*, 1954; Wren and Vos, 1961; Allen, 1964). None of these investigations utilized a large population sample unselected on the basis of blood group or pregnancy history and comprising all reported fetal deaths and concurrently reported live births. Therefore, to clarify the direct relationship of maternal ABO and Rh types to fetal wastage, and to re-evaluate various interpretations of the effect of ABO and Rh incompatibility singly and in combination, the examination of a large body of data from the New York City live birth and fetal death records over the years 1954–1959 was undertaken.

All records of fetal deaths reported in New York City for those six years (129,815) and a 10% sample of certificates of all live births (100,973) originally were collected by Dr. Tracy M. Sonneborn at Indiana University for an analysis of the effect of paternal age on fetal loss. Subsequently, other information (such as blood groups, maternal age, and certain background data), specific for a sizeable proportion of the

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series, was examined by Dr. Howard B. Newcombe and the results were published (1963). Since no attempt was made to analyze all the relevant data, Dr. Newcombe urged that further studies be done and, with Dr. Sonneborn's approval, made the computer tapes available for that purpose. An unusual opportunity to obtain pertinent information on a rather large scale was thereby provided, especially since in New York City all products of conception are registrable by law, regardless of gestational age. Despite the likelihood of a considerable amount of underreporting of fetal loss, both the size and the nature of the data have made possible the exploration of interrelationships not previously considered feasible.

Three aspects of maternal ABO and/or Rh types and fetal mortality have been considered: (1) the impact of single system blood-group incompatibility on risk of fetal death to white and Negro mothers; (2) the gestational age at which fetal deaths occur in single-system incompatibility, both ABO and Rh; and (3) the effect of various combinations of ABO and Rh compatibility and incompatibility on fetal wastage.

METHOD

The source of the data and method of extraction have already been described (Newcombe, 1963). In the present study, additional validation procedures and consistency checks were carried out. First, to determine whether the blood types derived from the computer tapes reflect maternal blood groups accurately, a systematic sample of 296 cases (live births and fetal deaths) was selected. There was 98.9% agreement between the maternal blood types on the computer tapes and those on the birth and fetal death certificates and 94% agreement between the certificates and the information furnished by hospitals and private physicians. Thus it is estimated that the agreement between coded data and medical records (hospital or physician) is well over 92% and probably close to 95%.

Second, the tabulations were checked for internal consistency, and, as a result, a change in coding procedure by the New York City Health Department eliminating maternal Rh type from code cards for 1957–1959 was discovered. In the analysis, therefore, maternal Rh types for 1954–1956 only are included, while maternal ABO types for all six years (1954–1959) are tabulated.

In order to detect any other internal discrepancies or reveal possible secular trends, the ABO data for 1954–1959 are examined separately for the two time periods, 1954–1956 and 1957–1959.

The terminology used in this study as well as the theoretically expected proportions of incompatible children are presented in Table 1. For simplicity, the term "Rh-negative mothers" is used for those so classified on birth certificates, although in some instances the "missing Rh-positive antigen" comprises a single attribute (Rh_o or D) and, in others, an antigenic complex including "C" alternatives and/or "E" alternatives, as in the "r" or "cde" individuals. Also, all Rh-negative mothers are referred to as "Rh-incompatible" since well over 60% of their fetuses would be Rh-incompatible, while Rh-positive mothers are always "Rh-compatible." Similarly, O mothers, since they would be expected to have the largest proportion of ABO-incompatible progeny, are considered "ABO-incompatible," in contrast to AB mothers, who are always "ABO-compatible."

The tables and figures in this analysis consist of two groups. The basic data with

ABO and Rh distributions as well as fetal death indices by race, by maternal age, and by length of gestation are presented in Appendix A, from which pertinent information is extracted for the tables and figures accompanying the text. In addition, because of the 1957 change in coding of Rh type mentioned above, a set of revised tables comparable to Tables 1 through 10 of Newcombe's original report (1963), and referred to in his letter to the editor (1965), appears in Appendix B. These are numbered according to the corresponding table numbers in the original publication, prefixed by "B" to distinguish them from those discussed in the text of this report. It

TABLE 1

DEFINITION OF TERMS

TERM	DEFINITION	APPROXIMATE FREQUENCY OF INCOMPATIBILITY	
		Whites	Negroes
Incompatibility.....	Blood group incompatibility: the situation where a dominant antigen is present in the fetus but absent in the mother		
Incompatible maternal blood types....	Those blood types where a dominant antigen is missing and thus a potentially incompatible situation could exist		
Maternal blood types:			
Rh-negative (Rh−)	Rh_0 (D) antigen missing; potentially Rh incompatible	61%	70%
Rh-positive (Rh+)	Rh_0 (D) antigen present; Rh compatible; *none* Rh incompatible	0%	0%
O.....	Both A antigen and B antigen missing; potentially ABO incompatible	32.5%	33.5%
B.....	A antigen missing; potentially ABO incompatible with regard to A	23.1%	19.8%
A.....	B antigen missing; potentially ABO incompatible with regard to B	9.4%	14.8%
AB.....	Neither A nor B antigen missing; ABO compatible; *none* ABO incompatible	0%	0%

NOTE.—Expectancies based on Rh frequencies for New York City whites and Negroes from Wiener and Wexler (1958) and ABO frequencies for whites from Tiber as quoted in Wiener (1943) and for Negroes from Landsteiner and Levine as quoted in Wiener (1943).

should be noted that, whereas in Newcombe's original tables all racial groups were pooled, each table of Appendix B presents the data by maternal racial classification. This was done because of the racial differences in blood-group distribution and fetal death indices as well as possible differences between whites and Negroes in the impact of certain blood-group incompatibilities upon fetal wastage.

Most tabulations are presented separately for "older" and "younger" maternal age groups, as well as for pooled maternal ages. Several considerations support the decision to use this simplified type of classification. While simultaneous subclassification by parity and maternal age would be desirable, such a detailed breakdown would be quite inefficient applied to these data because of the large number of empty cells that would result from multiple cross-classification. Another appropriate subclassification would be based simply on parity, since it is well recognized that the manifes-

tation of negative selection in Rh-incompatible mothers occurs only after Rh-isoimmunization, usually as a result of sensitizing pregnancies; and, consequently, the most meaningful analyses regarding Rh effects would pertain to multiparous mothers. In these data, however, it is not feasible to use reported parity, due to the fact that history of past pregnancies, known to be of questionable reliability when available, while recorded for 99% of mothers of live births is totally lacking for over 11% of mothers of dead fetuses. Thus, use of parity would result in a different degree of completeness for fetal deaths and live births and would possibly entail numerator-denominator biases in the computed fetal death indices. Moreover, even if the data on parity were complete and accurate, such a breakdown by birth order with maternal ages pooled would produce classes that are internally highly heterogeneous with regard to maternal age and thus with regard to those increased risks to the fetus of nongenetic kinds that are associated with advancing maternal age. In a circular manner this, too, could lead to unequal representation of maternal age groups in numerators and denominators—and, possibly to considerable distortion, especially in subclasses involving small numbers.

Since, on the other hand, maternal age is recorded on almost all certificates used (birth or death), the completeness and relative reliability of maternal age data provided a convincing reason for the use of gross maternal age classifications to serve the dual function of controlling on the important age parameter in over-all risk of obtaining categories that separate most of the primiparas from the multiparas.

To attain maximum effectiveness of this procedure, several maternal age classification schemes are utilized in the different analyses. Thirty years of age seems to provide a satisfactory separation of multiparous mothers from those in their first or second pregnancy. On the other hand, 25 years yields a more sizeable portion of the sample for analysis in the older group.

In general, although the approach and mode of analysis differ, the statistical procedures used in this study are similar to those of Newcombe (1963), including relative ratios, the χ^2 test of significance, and various modifications thereof (Cochran, 1954; Woolf, 1955; Haldane, 1955–1956; Roberts, 1957). The "fetal death index" (F.D.I.) used throughout corresponds to the "% fetal deaths" designated by Newcombe and is computed by multiplying the ratio of fetal deaths to 10 times the live births (since live births here constitute a 10% sample) by 100.

RESULTS

Table 2 presents the ABO distribution of white and Negro mothers of live births and fetal deaths occurring 1954–1959, as well as the fetal death index for each maternal ABO type. Table 3 presents the maternal ABO and Rh distributions with fetal death indices for 1954–1956.

The difference in F.D.I. between Negroes and whites is statistically significant (Table 2). Moreover, white and Negro mothers also differ in a number of factors, both biological and nonbiological, that are known or suspected to be related to risk of fetal death, such as the following: ABO distribution (1954–1959), Rh distribution (1954–1956), age distribution (1954–1959), number of pregnancies (1954–1959), history of prior fetal deaths (1954–1959), and attendant at delivery (1954–1959) (Tables 1 and 2, Appendix Tables A1, A4, A5, A6). Each comparison is statistically significant at

TABLE 2

Distribution of New York City Live Births and Fetal Deaths by Race and ABO Blood Group of Mother (1954–1959)

Blood Group	Whites						Negroes					
	Blood Group Distribution					Fetal Death Index	Blood Group Distribution					Fetal Death Index
	Live Births		Fetal Deaths		Population* (%)		Live Births		Fetal Deaths		Population† (%)	
	N	%	*N*	%			*N*	%	*N*	%		
O	36,230	47.34	17,575	49.82	45.6	4.85	7,867	50.79	6,226	49.84	44.2	7.91
A	27,955	36.53	12,525	35.50	36.4	4.48	3,932	25.39	3,295	26.38	30.3	8.38
B	9,220	12.05	3,821	10.83	13.5	4.14	3,109	20.07	2,435	19.49	21.8	7.83
AB	3,127	4.09	1,357	3.85	4.5	4.34	581	3.75	536	4.29	3.7	9.23
Total	76,532	100.01	35,278	100.00	100.0	4.61	15,489	100.00	12,492	100.00	100.0	8.07

Note.—Fetal death index = [fetal deaths/live births (10% sample) × 10] × 100.

* For United States, from Tiber after Wiener (1943).

† For Negroes, New York City, from Landsteiner and Levine after Wiener (1943).

TABLE 3

Distribution of New York City Live Births and Fetal Deaths by Race and ABO-Rh Blood Groups of Mother (1954–1956)

Maternal Blood Type	Whites						Negroes					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
O:												
L.B.	15,912	47.19	2,129	45.71	18,041	47.01	3,369	51.22	254	50.60	3,623	51.17
F.D.	7,581	49.43	1,108	47.07	8,689	49.12	2,667	50.91	155	44.80	2,822	50.53
F.D.I.	4.76		5.20		4.82		7.92		6.10		7.79	
A:												
L.B.	12,252	36.33	1,798	38.60	14,050	36.61	1,649	25.07	121	24.10	1,770	25.00
F.D.	5,513	35.95	848	36.02	6,361	35.96	1,337	25.52	105	30.35	1,442	25.82
F.D.I.	4.50		4.72		4.53		8.11		8.68		8.15	
B:												
L.B.	4,169	12.36	545	11.70	4,714	12.28	1,298	19.73	104	20.72	1,402	19.80
F.D.	1,670	10.89	300	12.74	1,970	11.14	1,032	19.70	73	21.10	1,105	19.79
F.D.I.	4.01		5.50		4.18		7.95		7.02		7.88	
AB:												
L.B.	1,389	4.12	189	3.99	1,575	4.10	262	3.98	23	4.58	285	4.03
F.D.	572	3.73	98	4.16	670	3.79	203	3.87	13	3.76	216	3.87
F.D.I.	4.12		5.27		4.25		7.75		5.65		7.58	
All ABO types:												
L.B.	33,722	100.0	4,658	100.0	38,380	100.0	6,578	100.0	502	100.0	7,080	100.0
F.D.	15,336	100.0	2,354	99.9	17,690	100.0	5,239	100.0	346	100.0	5,585	100.0
F.D.I.	4.55		5.50		4.61		7.96		6.89		7.89	

Note.—L.B. = live births; F.D. = fetal deaths; F.D.I. = fetal death index.

the .0001 level, whether based on live births or fetal deaths. Therefore, to prevent confounding the analysis of the effects of blood groups on fetal death with other factors, all subsequent tabulations present the data for whites and Negroes separately.

The results regarding each of the three aspects under consideration are presented in the sequence indicated previously.

I. Blood-Group Incompatibility and Fetal Loss in White and Negro Mothers

When white mothers are classified by ABO and Rh types, their patterns of fetal loss are consistent with selection due to blood-group incompatibility reported in previous studies.

First, white mothers of all types potentially capable of bearing ABO-incompatible fetuses, except B, have greater fetal loss than AB mothers who could not have ABO-incompatible fetuses (Fig. 1).* In both time periods (1954–1956 and 1957–1959), white O mothers show a significantly higher risk than AB mothers (11%–12% higher) —even higher than pooled non-O mothers (9%–12%), although the latter, of course, include not only the always ABO-compatible AB mothers but also A and B mothers with some incompatible fetuses as well. When, to avoid any effects of ABO-Rh interaction, only Rh-compatible (i.e., Rh-positive) mothers are studied with regard to the effect of missing A and B antigens, the pattern of high fetal loss to O mothers as compared to AB mothers is confirmed (Fig. 2). This effect appears in both younger and older maternal age groups, although it seems most distinct in the 25–29-year group. When that five-year period is included, the O/AB ratio shows a clearer deviation from 1.00 in both younger and older categories than when it is excluded (i.e., 1.20 and 1.19, both significantly greater than unity, for the "under 30" and "25+" age categories, but 1.19 and 1.12, neither statistically significant, for the "under 25" and "over 30" age categories). This age effect, more pronounced in the middle segment than as a linear increase with age, is noteworthy, since Kirk and co-workers (1953) also reported a similar ABO-related differential pregnancy experience with age—the deficiency of children born to O mothers as compared to ABO-compatible mothers occurring primarily in the 25–35-year age group in their series, although the pattern was not detectable in their later series (Kirk and co-workers, 1955).

Second, the effect of maternal Rh type on fetal loss in white mothers is shown in Figure 3. White Rh-negative (thus potentially Rh-incompatible) mothers have a higher risk of fetal loss than corresponding Rh-positive mothers, whether ABO types are pooled or whether each ABO type is considered separately, and whether all ages are combined or only those 25 years and over or 30 years and over are considered. The differences are statistically significant for pooled ABO types of combined age groups as well as for older mothers and for some individual ABO types. The pattern is consistent with the expected effect of increasing risk of maternal Rh-isoimmunization with higher parity and the association of parity with maternal age; that is, the groups of older mothers have higher Rh−/Rh+ F.D.I. ratios than younger mothers (1.15 and 1.14 for combined ABO types of "30+" and "25+" groups, respectively,

* The only possible slight deviation from the total pattern of increased fetal loss with ABO incompatibility appears in the relatively low F.D.I.'s for B mothers, for whom the numerical rates appear to fall below AB mothers (Figs. 1 and 2). However, these slight differences, which occur not only in Rh-positive mothers but also in those of pooled Rh types, are not statistically significant and may be due to chance and/or ethnic, racial, or socioeconomic stratification in the population.

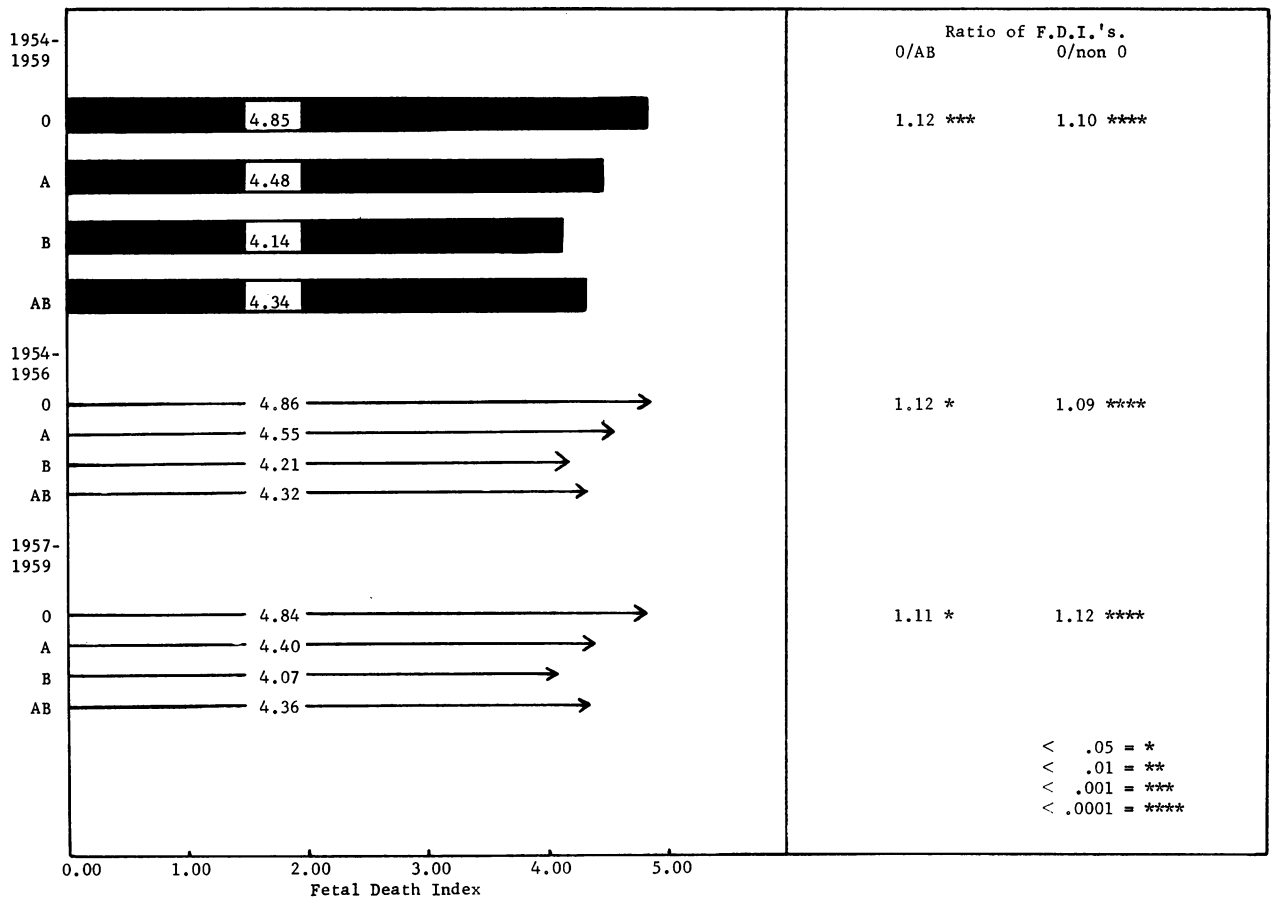

FIG. 1.—Fetal death index for white mothers by ABO type (all ages and Rh types)

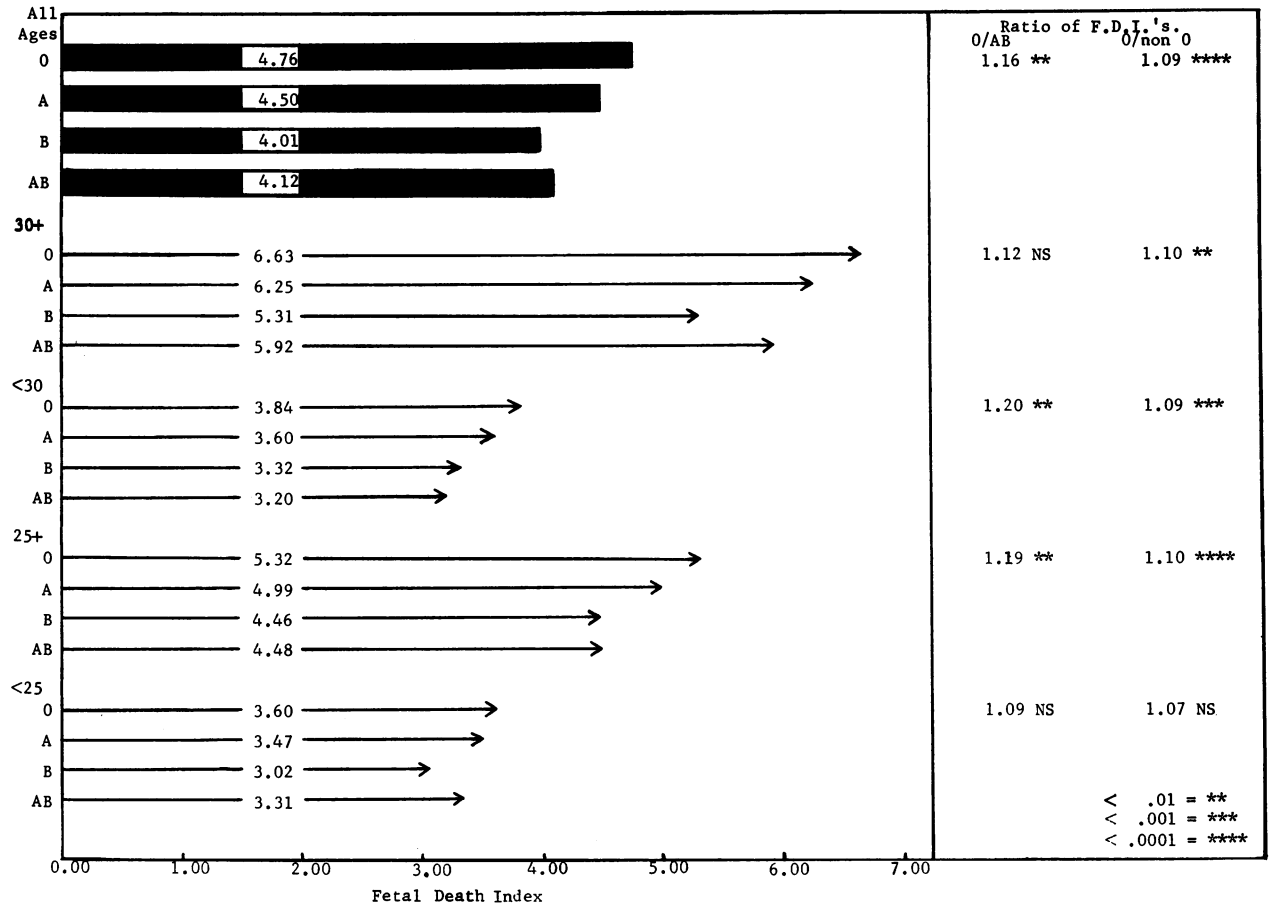

FIG. 2.—Fetal death index for Rh-positive white mothers by maternal age and ABO type (1954–1956)

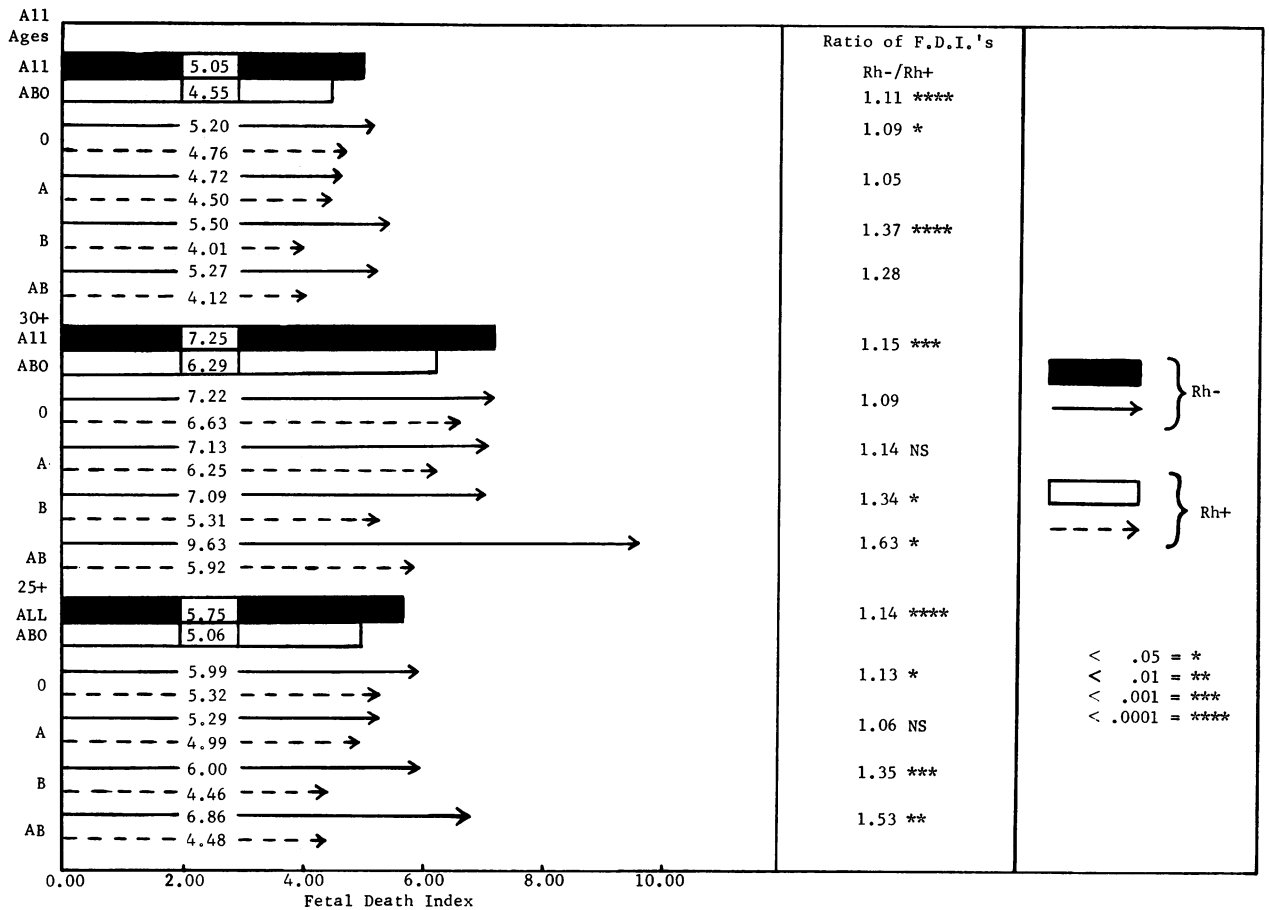

FIG. 3.—Fetal death index for Rh-negative and Rh-positive white mothers (1954–1956)

as compared with 1.08 and 1.03 for the "under 30" and "under 25" groups, respectively [Fig. 3 and Appendix Table A7]).

Among Negro mothers, however, there is no evidence for negative selection associated with Rh incompatibility, nor is there a clear pattern of ABO-incompatibility manifestation similar to that in white mothers of this or previously published series. Not only are the over-all rates of fetal loss for Negro mothers much higher than for white mothers (Tables 2 and 3) but the patterns of fetal loss for Negroes of various ABO types are erratic, with different trends for the two time periods (Fig. 4). In fact, for the 1957–1959 period, the risk of fetal loss is significantly *lower* for O (incompatible) mothers than for AB mothers ($P < .001$)!

The effect of Rh incompatibility in Negro mothers also differs from previously reported patterns (Fig. 5); instead of higher fetal death rates, lower rates are observed for Rh-negative than for Rh-positive mothers. This effect appears in Negro mothers of pooled ABO types for all ages combined and in those over 30 years of age considered separately, with levels of statistical significance attained in O mothers and those of pooled ABO types.

To explore the basis for these unusual findings in Negro mothers, particularly the aberrant Rh pattern, possible sources of distortion, such as maternal age distribution, prior fetal loss, and available socioeconomic parameters, require examination. First, with respect to maternal age, it is clear that the Negro mothers differ from the whites, with the greatest difference in mothers under 20 years (Appendix Table A1). The proportion of Negro mothers in that age group is almost three times that for whites. Nevertheless, this difference could not be responsible for the observed white-Negro difference in Rh effect, because: (1) that age group does not show the difference in question; (2) it does not represent a large proportion of total births; and (3) the F.D.I.'s in that group are not exceptionally high (Table 4). Actually, the higher F.D.I. for Negro Rh-positive mothers appears first in the 20–24-year maternal age group, which represents 31.5% of Negro mothers, not extremely different from whites (27.6%) (Appendix Table A3). Furthermore, in terms of parity, recognized to be the critical parameter in Rh-negative selection, the Negroes in the 20–24-year age group are probably more comparable to the next oldest group of whites (25–29), which constitutes 33.8% of white mothers and thus is likewise comparable in proportional representation. The other Negro age group with aberrant Rh−/Rh+ F.D.I. ratios is the 30–39-year age group, which together with the 20–24 age group constitutes 57.2% of Negroes, compared with 58.8% of whites. Finally, it is noteworthy that the most marked Rh selection effect in whites occurs after 30 years of age, representing 33.6% of white mothers. Among Negroes, this includes 27.?% of mothers—certainly not very different from that in white mothers; and, if it is reasoned that because of earlier initiation of reproduction Negro mothers arrive at a similar parity to white mothers one five-year age group sooner, then over 54.6% of all Negro mothers would have reached the age groups expected to show Rh-negative selection comparable to that of white mothers over 30 years of age.

Previous history of fetal loss also cannot account for the unusual findings in Negro mothers (Table 4). The F.D.I.'s for Rh-negative Negro mothers are lower than for Rh-positives, regardless of whether there have been prior fetal deaths (Rh− = 12.56, Rh+ = 16.63) or no prior fetal wastage (Rh− = 5.07, Rh+ = 5.80), whereas the

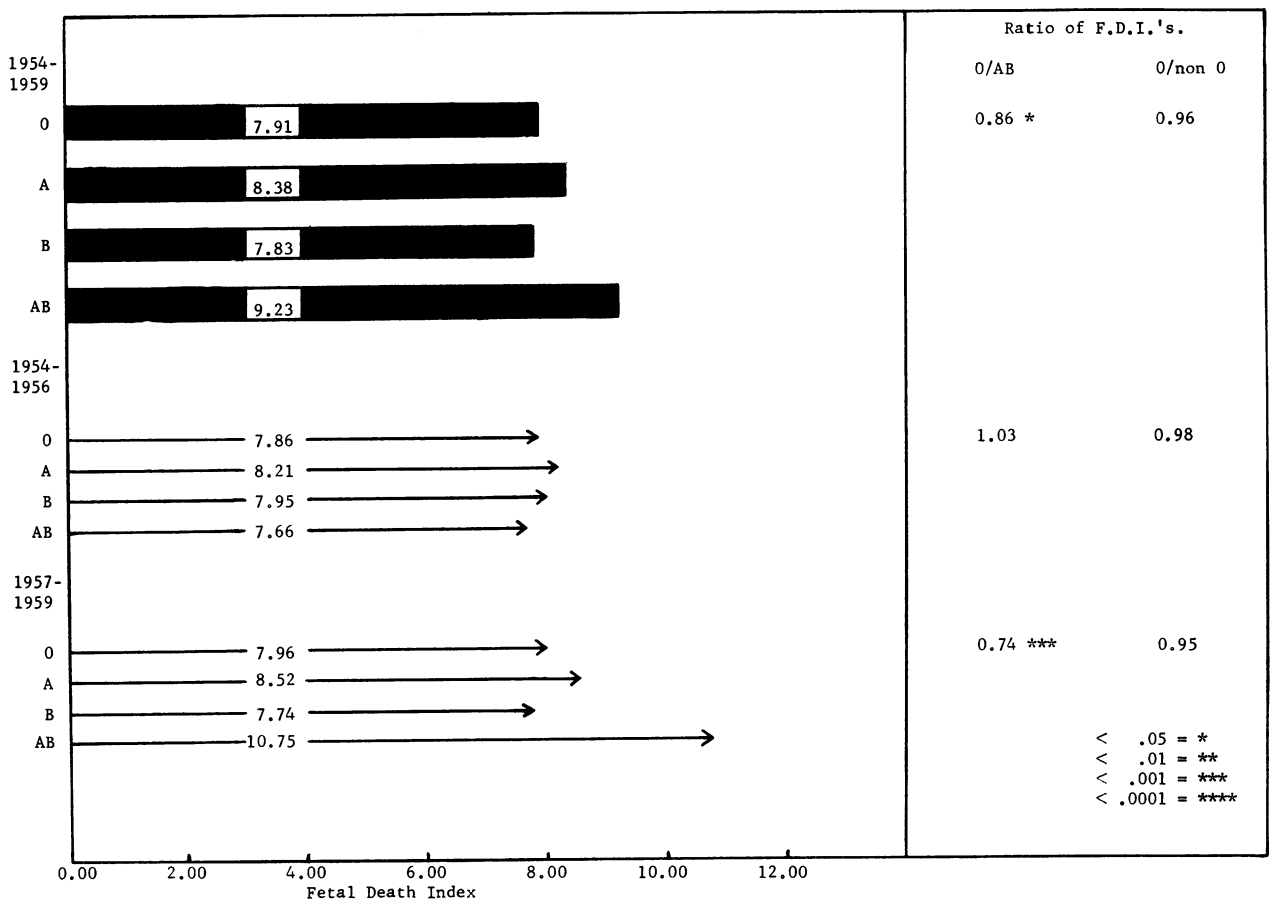

FIG. 4.—Fetal death index for Negro mothers by ABO type (all ages and Rh types)

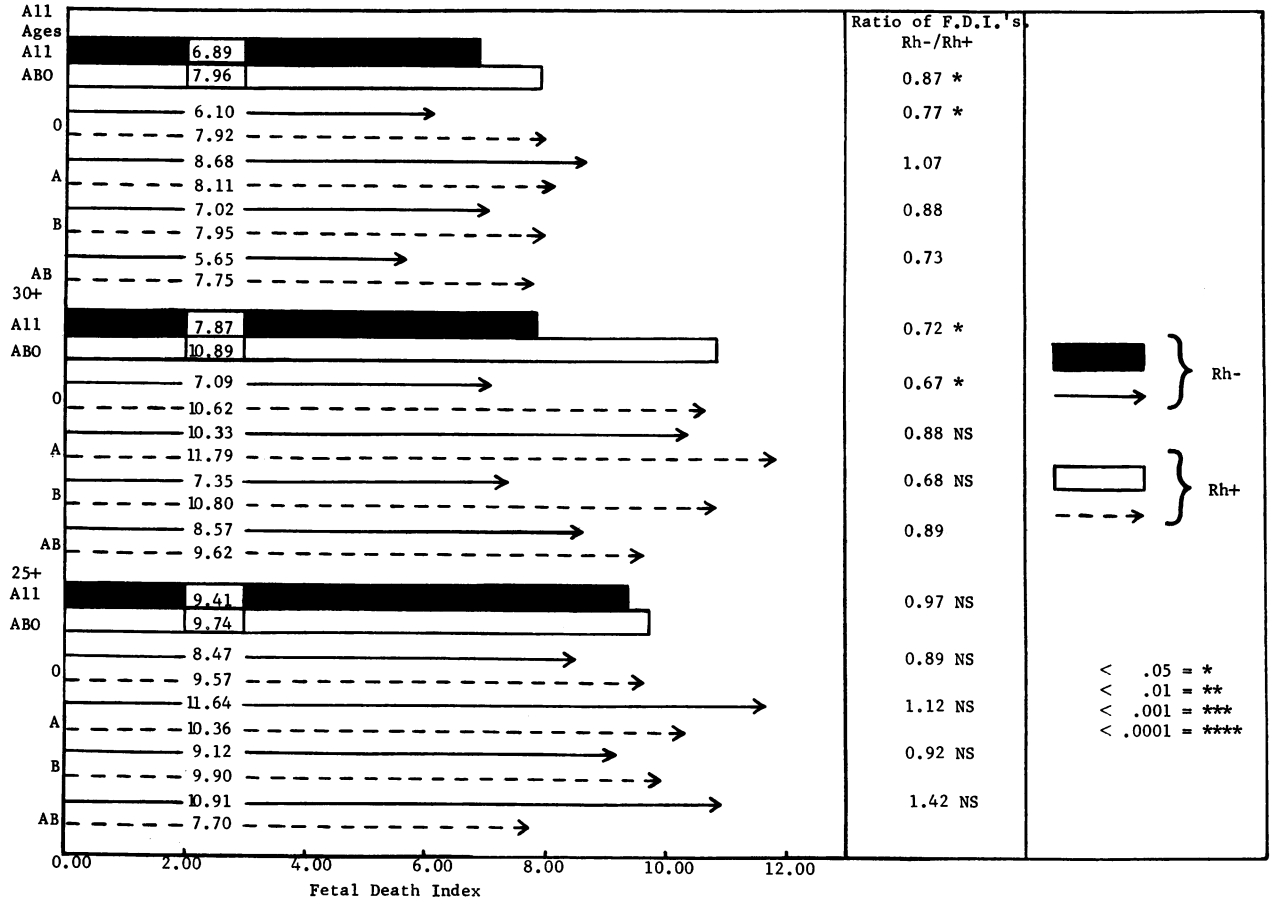

FIG. 5.—Fetal death index for Rh-negative and Rh-positive Negro mothers (1954–1956)

pattern is the reverse among white mothers with prior wastage (Rh− = 12.09, Rh+ = 11.03) and without (Rh− = 3.77, Rh+ = 3.52). Although not all of these differences are statistically significant, the pattern is consistent. Moreover, within each maternal age group, the trend in Rh−/Rh+ ratios for Negro mothers is the same for those with as for those without previous history of fetal death, except in the 40–49 age group, where numbers are too small for consideration.

Finally, Rh-negative and Rh-positive mothers can be compared in terms of the only index of socioeconomic status available on certificates: whether mothers were delivered on a private service, a ward service, or other than a hospital service. Clearly, there are no differences in the distributions: Rh-positive Negro mothers are very

TABLE 4

FETAL DEATH INDEX BY MATERNAL AGE, RH TYPE, AND PRIOR FETAL DEATHS FOR WHITE AND NEGRO MOTHERS (1954-1956)

MATERNAL AGE	PRIOR FETAL DEATHS	WHITE MOTHERS				NEGRO MOTHERS			
		Rh+		Rh−		Rh+		Rh−	
		L.B. (*N*)	F.D.I.	L.B. (*N*)	F.D.I.	L.B. (*N*)	F.D.I.	L.B. (*N*)	F.D.I.
<20	0	1,676	2.71	238	2.06	911	3.25	49	5.10
	1+	62	13.87	7	20.00	35	22.29	2	45.00
20–24	0	8,608	2.97	1,169	2.94	1,810	5.13	166	3.07
	1+	790	9.77	109	12.57	253	17.15	31	6.77
25–29	0	9,847	3.07	1,345	3.30	1,376	6.39	70	9.00
	1+	1,587	8.66	259	9.61	442	15.66	34	17.06
30–39	0	8,482	4.34	1,122	5.07	1,142	7.78	93	5.05
	1+	1,941	12.24	305	12.75	524	16.39	51	11.57
40–49	0	546	9.87	74	11.35	46	15.87	3	23.33
	1+	179	23.58	29	23.45	37	22.70	3	16.67
Total*	0	29,159	3.52	3,948	3.77	5,285	5.80	381	5.07
	1+	4,559	11.03	709	12.09	1,291	16.63	121	12.56

* Includes mothers for whom age and prior history of fetal loss were recorded.

similar to Rh-negatives, with 9.9% and 9.3%, respectively, on private service and 87.7% and 89.1%, respectively, on general service. Thus, medical attendant at delivery as well as maternal age distribution and prior history of fetal loss can be ruled out as possible factors distorting the biological Rh effects.

Since the higher F.D.I.'s for Rh-positive than for Rh-negative Negro mothers remain as yet unexplained, and since the erratic ABO observations differ from those for white mothers of this study and previously published reports, the detailed analysis of the data concerning ABO-Rh interaction and the time of manifestation of the effects of incompatibility has been limited to white mothers.

II. Gestational Age of Fetal Deaths in ABO Incompatibility and Rh Incompatibility

To examine the time of manifestation of prenatal selection associated with the various blood-group incompatibilities, fetal deaths occurring in white mothers are

classified by length of gestation. Early fetal deaths are defined as those occurring at under 20 weeks of gestational age; late fetal deaths, 28 weeks and over. The statistics for the interim period (20–27 weeks) are available for reference but are not included in the analysis, since this period is used as a gap period to avoid any erroneous classification of "early" and "late."

The F.D.I.'s for white mothers of all age groups (Table 5) reveal a definite association of ABO-incompatibility with early fetal loss. The highest early F.D.I.'s occur among O mothers whose risk is significantly greater than AB mothers; the O/AB ratio of F.D.I.'s ranges from 1.19 to 1.26, depending on maternal age category. When eliminating any influence of Rh incompatibility by considering only Rh-positive mothers, the ABO pattern is similar, with the clearest effect shown in age categories that include 25–29-year-old mothers (25+ and under 30). Early F.D.I.'s are highest

TABLE 5

EARLY FETAL DEATHS TO WHITE MOTHERS BY MATERNAL AGE AND ABO TYPE

Maternal Age Groups	All Rh Type Mothers (1954–1959)						Rh+ Mothers Only (1954–1956)					
	O	A	B	AB	Comparison Ratios		O	A	B	AB	Comparison Ratios	
					O/AB	O/non-O					O/AB	O/non-O
30+:												
L.B.	11,645	9,059	3,029	1,033			5,184	4,095	1,407	468		
F.D.I.	4.44	4.08	3.46	3.72	1.19**	1.14****	4.43	4.19	3.40	3.87	1.15 N.S.	1.11**
<30:												
L.B.	24,583	18,891	6,188	2,094			10,738	8,164	2,762	922		
F.D.I.	2.48	2.21	2.00	2.01	1.24***	1.16****	2.51	2.34	2.06	1.77	1.42****	1.13****
25+:												
L.B.	23,602	18,262	6,090	2,112			10,598	8,217	2,815	960		
F.D.I.	3.59	3.22	2.85	2.96	1.21****	1.15****	3.55	3.33	2.87	2.77	1.28***	1.12****
<25:												
L.B.	12,626	9,688	3,127	1,015			5,324	4,042	1,354	430		
F.D.I.	2.21	2.06	1.75	1.75	1.26****	1.12****	2.30	2.20	1.77	1.81	1.27 N.S.	1.11*

NOTE.—F.D.I. (early) = fetal death index for gestational age of less than 20 weeks.
N.S. = not significant
* $P < .05$.
** $P < .01$.
*** $P < .001$.
**** $P < .0001$.

for O mothers, who have a much greater risk than AB mothers of similar age group: 15% higher (N.S.) among older and 42% higher among younger mothers, with 30 years as the boundary between older and younger, and 27%–28% higher for younger and older maternal categories, with 25 years as the boundary.

On the other hand, there is no such consistent difference in late fetal deaths, regardless of maternal age classification or separation of Rh compatibles only (Table 6). The late F.D.I.'s for O mothers are as low or even lower than those for AB mothers, yielding O/AB ratios below unity or about unity. Only with a pooled non-O denominator is there one high ratio (1.09 for mothers over 25 years of age); and this is clearly not because of higher values for the ABO-incompatible O mothers than for always ABO-compatible AB mothers, but rather because of the relatively low F.D.I. values for the denominator's A and B mothers who sometimes are ABO-incompatible. It is, therefore, apparent that loss due to ABO incompatibility does not contribute to late fetal wastage.

TABLE 6

Late Fetal Deaths to White Mothers by Maternal Age and ABO Type

Maternal Age Groups	All Rh Type Mothers (1954–1959)						Rh+ Mothers Only (1954–1956)					
	O	A	B	AB	Comparison Ratios		O	A	B	AB	Comparison Ratios	
					O/AB	O/non-O					O/AB	O/non-O
30+:												
L.B.	11,645	9,059	3,029	1,033			5,184	4,095	1,407	468		
F.D.I.	1.62	1.54	1.49	1.68	0.96 N.S.	1.05 N.S.	1.52	1.42	1.29	1.50	1.02 N.S.	1.09 N.S.
<30:												
L.B.	24,583	18,891	6,188	2,094			10,738	8,164	2,762	922		
F.D.I.	0.93	0.88	0.91	0.96	0.97 N.S.	1.03 N.S.	0.90	0.84	0.78	0.95	0.94 N.S.	1.07 N.S.
25+:												
L.B.	12,009	9,432	3,200	1,081			10,598	8,217	2,815	960		
F.D.I.	1.31	1.19	1.17	1.38	0.94 N.S.	1.09*	1.22	1.13	1.04	1.19	1.02 N.S.	1.09 N.S.
<25:												
L.B.	6,044	4,624	1,514	495			5,324	4,042	1,354	430		
F.D.I.	0.90	0.86	0.83	1.05	0.85 N.S.	1.03 N.S.	0.87	0.85	0.76	1.02	0.85 N.S.	1.04 N.S.

Note.—F.D.I. (late) = fetal death index for gestational age of 28 weeks or more.
N.S. = not significant.
* $P < .05$.

TABLE 7

Early and Late Fetal Deaths to Rh-Negative and Rh-Positive White Mothers by Maternal Age (1954–1956)

Maternal Age Groups	Early Fetal Deaths						Late Fetal Deaths					
	All ABO Type Mothers			AB (ABO-compatible) Mothers Only			All ABO Type Mothers			AB (ABO-compatible) Mothers Only		
	Rh−	Rh+	Comp. Ratios Rh−/Rh+	Rh−	Rh+	Comp. Ratios Rh−/Rh+	Rh−	Rh+	Comp. Ratios Rh−/Rh+	Rh−	Rh+	Comp. Ratios Rh−/Rh+
30+:												
L.B.	1,528	11,154		54	468		1,528	11,154		54	468	
F.D.I.	4.02	4.19	0.96 N.S.	4.26	3.87	1.10 N.S.	2.39	1.46	1.64**	4.81	1.50	3.22**
<30:												
L.B.	3,131	22,586		132	922		3,131	22,586		132	922	
F.D.I.	2.26	2.36	0.96 N.S.	1.89	1.77	1.07 N.S.	1.25	0.87	1.44**	1.29	0.95	1.35 N.S.
25+:												
L.B.	3,132	22,590		121	960		3,132	22,590		121	960	
F.D.I.	3.22	3.35	0.96 N.S.	3.39	2.77	1.22 N.S.	1.89	1.16	1.62**	2.89	1.19	2.44**
<25:												
L.B.	1,527	11,152		65	430		1,527	11,152		65	430	
F.D.I.	2.06	2.18	0.94 N.S.	1.08	1.81	0.59 N.S.	1.07	0.85	1.26*	1.23	1.02	1.20 N.S.

Note.—N.S. = not significant.
* $P < .05$.
** $P < .0001$.

In contrast to ABO incompatibility, Rh incompatibility tends to manifest itself in late fetal deaths (Table 7). Rh-negative white mothers of pooled ABO types have a significantly higher risk of late fetal deaths than Rh-positive white mothers of corresponding age groups. With 30 years as the age boundary, the F.D.I. appears to be over 60% higher for older ($P < .0001$) and over 40% higher for younger Rh-negative mothers, with 25 years as the maternal age boundary, over 60% higher for the older category ($P < .0001$) and still over 25% higher for younger mothers ($P < .05$). Yet, for early fetal wastage there are no significant differences between Rh-negative and Rh-positive mothers, regardless of maternal age.

If the analysis is confined to AB mothers to eliminate any interaction of ABO incompatibility, the increase in late fetal deaths associated with Rh incompatibility is even more marked, especially in older mothers. For those beyond 25 years of age, the critical ratio is more than twice unity, and for those beyond 30, over three times, without any significant difference in early fetal deaths to mothers in any of the age groups.

The same patterns of ABO and Rh effects are also clearly evident when the percentage distribution of total fetal deaths by gestational age of occurrence is examined. ABO-incompatible (O) mothers show a higher proportion of fetal wastage early in pregnancy than do ABO-compatible (AB) mothers (65.8% versus 59.6% for pooled Rh types; 67.2% versus 61.3% for Rh-positive mothers only). Also, Rh-negative mothers show a notably larger proportion of fetal loss in late pregnancy than do Rh-positive mothers (32.7% versus 23.7%); this is consistent for each ABO type.

Clearly, each of the incompatibilities, ABO and Rh, shows a distinct and different temporal pattern: the selection of ABO incompatibility is manifest primarily in early fetal wastage, while the selection of Rh incompatibility is manifest primarily in late fetal deaths.

III. Combinations of Incompatibility and Compatibility in the ABO and Rh Systems: ABO-Rh Interaction

While it is feasible to consider the effects of each system separately, in reality mothers and their fetuses are subject to the action of both their ABO and Rh genotypes. Accordingly, they should be studied simultaneously to determine whether ABO-Rh effects are simply additive or interact in a more complex manner.

If the effects of the ABO and Rh systems are simply additive, then several additivity hypotheses can be examined in terms of the following: (1) the *number of systems* in which incompatibility exists; (2) the sum of the combined *number of missing antigens* in both systems; and (3) the total *expected proportion of incompatible offspring* irrespective of whether these offspring are incompatible in a single system or in both systems. A fourth additivity hypothesis (4) incorporating the assumption that Rh incompatibility makes a proportionately similar and additive contribution to the total expected proportion of incompatibles of each maternal ABO type can be examined in terms of the expected proportions of ABO-incompatible offspring of Rh-negative mothers. It should be noted that these hypotheses are not mutually exclusive, but represent different facets of the additivity concept.

In Table 8, expectancies for each additivity hypothesis are presented along with the observed total, early, and late gestational F.D.I.'s for each maternal ABO-Rh

TABLE 8

TESTS OF ADDITIVITY HYPOTHESES BASED ON FETAL DEATH INDEX AND ABO-RH INCOMPATIBILITY STATUS

EXPECTANCIES				OBSERVED FETAL DEATH INDEX BY GESTATIONAL PERIOD															
				Fetal Deaths: All Gestational Ages (Total F.D.I.'s)					Early Fetal Death (Early F.D.I.'s)					Late Fetal Death (Late F.D.I.'s)				
No. Incompatible Systems—Hypothesis (1)	No. Missing Antigens—Hypothesis (2)	Exp. Prop. ABO and/or Rh Incompatible Offspring*—Hypothesis (3)	Exp. Prop. ABO Incompatible Offspring*—Hypothesis (4)	Blood Group	Maternal Age					Maternal Age					Maternal Age				
					All Ages	30+	<30	25+	<25	All Ages	30+	<30	25+	<25	All Ages	30+	<30	25+	<25
AB+ [None]	AB+ [None]	AB+ None [none]	.....	AB+	4.12	5.92	3.20	4.48	3.31	2.48	3.87	1.77	2.77	1.82	1.14	1.50	0.96	1.19	1.03
.....	A+	A+ .094 [1]	.....	A+	4.50	6.25	3.60	4.99	3.47	2.97	4.19	2.34	3.33	2.20	1.04	1.42	0.84	1.13	0.85
.....	B+ [1]	B+ .231 [2]	.....	B+	4.01	5.31	3.32	4.46	3.02	2.52	3.41	2.06	2.87	1.77	0.95	1.29	0.78	1.04	0.76
AB− [1-2]....	AB−	AB− .617 [4]	None [none]	AB−	5.27	9.63	3.48	6.86	2.31	2.58	4.26	1.89	3.39	1.08	2.31	4.81	1.29	2.89	1.23
.....	A−	A− .653 [5]	.094 [1]	A−	4.72	7.13	3.51	5.29	3.44	2.74	4.29	1.98	3.08	2.01	1.40	2.02	1.09	1.61	0.95
.....	B− [2]	B− .705 [6]	.231 [2]	B−	5.50	7.09	4.68	6.00	4.25	3.10	3.90	2.67	3.45	2.19	1.91	2.64	1.54	2.10	1.44
O+ [1-2]....	O+	O+ .325 [3]	.....	O+	4.76	6.63	3.84	5.32	3.60	3.15	4.43	2.51	3.55	2.31	1.10	1.52	0.90	1.22	0.87
O− [3]....	O− [3]	O− .741 [7]	.325 [3]	O−	5.20	7.22	4.18	5.99	3.64	2.89	3.81	2.43	3.26	2.16	1.68	2.44	1.30	1.98	1.09

NOTE.—Numbers in brackets indicate "expected" rank order of F.D.I.'s according to increasing magnitude, i.e., none, 1, 2, 3, . . . etc. Exp. prop. = expected proportion.

* Using Tiber frequencies for New York whites after Wiener (1943).

phenotype by maternal age category. The expectancies in parentheses are expressed in terms of expected rank of F.D.I. values in order of increasing magnitude from "none" for the maternal type with lowest F.D.I. expectancy through "3" for hypotheses (1) and (2), through "7" for hypothesis (3) where the computed proportion of incompatible offspring is indicated for each maternal ABO-Rh phenotype, and through "3" for hypothesis (4) where the computed proportion of ABO-incompatible offspring is specified for Rh-negative mothers only.

Additivity Hypothesis (1). With O and AB representing ABO-incompatible and ABO-compatible types, respectively, and Rh-negative and Rh-positive representing Rh-incompatible and Rh-compatible types, respectively, the following four maternal blood-group combinations are derived for comparisons: (1) O− mothers representing the double system incompatibles (ABO and Rh); (2) O+ mothers representing single system incompatibles (ABO); (3) AB− mothers representing single system incompatibles (Rh); and (4) AB+ mothers representing the double system compatibles.

If the effects of the two systems are simply additive, according to hypothesis (1), one would expect that mothers compatible in both systems would have the lowest fetal death rates and those incompatible in both systems the highest. However, F.D.I.'s for all gestational ages show that while doubly compatible mothers (AB+) tend to have low indices they are not always the lowest; and the double system incompatibles (O− mothers) do not have the highest F.D.I. in any maternal age group examined (Table 8). In fact, the risk of fetal death to O− mothers appears lower than for AB− mothers for pooled maternal ages, and it is relatively lower even when older mothers only are considered, although the deviations in these O/AB ratios are not statistically significant.

Moreover, analysis of fetal deaths subclassified by gestational age is consistent with the observations based on total gestational periods. Neither in early nor in late fetal deaths do the double system incompatibles (O−) show the highest F.D.I.'s, whether mothers of pooled ages or older or younger age groups are considered (Table 8).

Additivity Hypothesis (2). Another test of additivity is to determine whether the observed F.D.I.'s increase with the number of missing maternal antigens in both the ABO and Rh systems, that is, whether those maternal types with no missing antigens (AB+) have the lowest F.D.I.'s, those with one missing antigen (A+, B+, AB−) have the next lowest, those with two missing antigens (A−, B−, O+) next, and those with three missing antigens (O−) have the highest F.D.I.'s.

Among mothers of all maternal ages, as well as among older mothers, AB Rh-negative mothers (missing only the Rh antigen) have total F.D.I.'s that exceed those for A−, O+, and O− maternal combinations missing two or three antigens (Table 8). In fact, in the older age groups (30+, 25+), AB− mothers have the highest total F.D.I.'s. Nor are AB− mothers the only exception to the hypothesis. For when the missing antigens are added together regardless of system and the mothers are classified so that those in each category contain the same specific number of missing antigens, the component types within each category show a wide range of F.D.I.'s overlapping into groups both lower and higher in cumulative number of missing antigens. For example, among mothers of all ages, B Rh-negative mothers with two missing

antigens (A and Rh) have a higher F.D.I. than O Rh-negative mothers with three missing antigens (A, B, and Rh), and A-negative and O-positive mothers, each with two missing antigens, have lower F.D.I.'s than AB-negative mothers with one missing antigen. Although the differences are not statistically significant, the heterogeneity within categories and the lack of clear differences between categories are apparent in all maternal age groups. When early and late fetal deaths are examined separately, the observations are similar to those for total fetal loss. Thus, regardless of maternal age (30+ or under 30 years, 25+ or under 25 years, as well as pooled ages) or gestational age of fetal death, there is neither a consistent increase nor decrease in fetal wastage according to the cumulative number of missing Rh and AB antigens (Table 8).

While it is clear that the total number of missing antigens in both systems and the F.D.I. are not positively correlated, nevertheless this method is an oversimplification, since adding the number of missing antigens gives each missing antigen an equal value, and it cannot be assumed that with each of the missing antigens the expected proportion of incompatible offspring would be similar.

Additivity Hypothesis (*3*). To test for additivity more specifically, the proportion of expected incompatible offspring in one or both systems for a given maternal type is computed on the basis of population gene frequencies and compared with the observed F.D.I.'s. A linear increase of F.D.I. with expected proportion of incompatibles would indicate additivity. However, as shown in Table 8, there is no such increase in total, early, or late fetal deaths, whether mothers of all ages or younger or older mothers only are considered.

Additivity Hypothesis (*4*). Since the ABO locus and Rh locus are independent genetic loci (i.e., not in the same linkage group), it is assumed that the expected proportion of Rh incompatibles should be the same regardless of ABO type. If ABO incompatibility and Rh incompatibility effects are independent and additive, Rh incompatibility should yield a similar additive contribution to the expected proportion of ABO-incompatible offspring. Consequently, another set of expectancies can be computed on the basis of ABO incompatibles only and applied to Rh-negative mothers of each ABO type. When the observed F.D.I.'s for Rh-negative mothers of different ABO types are compared with the expected proportion of ABO incompatibles for those types, no consistent relationship is observed for total, early, or late F.D.I.'s in any maternal age series. In fact, among the older Rh-negative mothers, regardless of whether 30 or 25 years of age and over is used, the Rh-negative group with the lowest quantitative expectancy (AB−) has the highest total F.D.I. and late F.D.I.

In summary, comparison of the observed F.D.I.'s with various sets of expected values and ranks, based on the sum of the incompatible systems, the total combined number of missing maternal antigens in both systems, or the expected proportion of incompatibles according to different hypotheses ([3] and [4]), all indicate that the effects of ABO incompatibility and Rh incompatibility are not simply additive. It follows, therefore, that there is some more complex type of relationship between ABO and Rh incompatibility. The next problem is to elucidate the nature of that interaction.

Two possible aspects of the postulated ABO-Rh interaction can be examined in terms of total fetal deaths and fetal deaths by gestational age of occurrence: (1) the

impact of ABO incompatibility on Rh-incompatibility selection and (2) the impact of Rh incompatibility on ABO-incompatibility selection.

In terms of total fetal deaths, an indicator of the first aspect of interaction would be the ratio of the F.D.I. of Rh-negative O mothers to that for Rh-negative AB mothers, with the numerator representing the resultant of both incompatibilities and the denominator the effect of Rh incompatibility in the absence of ABO incompatibility. An estimate of the simple effect of ABO incompatibility may be derived from the O+/AB+ ratio used in comparison. An O−/AB− ratio significantly under 1.0, with an O+/AB+ ratio ≥ 1.0, would thus suggest a favorable effect of ABO incompatibility on Rh-incompatibility selection.

In Table 9, the ratio O/AB for total fetal deaths to older Rh-negative mothers is observed to be below unity, although not statistically significant (0.75 for mothers beyond 30 and 0.87 for mothers beyond 25), while the ratios for Rh-positive mothers

TABLE 9

O/AB RATIOS AND RH−/RH+ RATIOS BASED ON FETAL DEATH INDEX (POOLED GESTATIONAL AGES) BY MATERNAL AGE

	All Ages	30+ Years	25+ Years	<30 Years	<25 Years
O/AB Ratios in:					
Rh− Mothers	0.99 N.S.	0.75 N.S.	0.87 N.S.	1.20 N.S.	1.58 N.S.
Rh+ Mothers	1.16**	1.12 N.S.	1.19**	1.20**	1.09 N.S.
Rh−/Rh+ Ratios in:					
O Mothers	1.09*	1.09 N.S.	1.13*	1.09 N.S.	1.01 N.S.
A Mothers	1.05 N.S.	1.14 N.S.	1.06 N.S.	0.97 N.S.	0.99 N.S.
B Mothers	1.37****	1.34*	1.35***	1.41***	1.41*
AB Mothers	1.28 N.S.	1.63*	1.53**	1.09 N.S.	0.71 N.S.

NOTE.—N.S. = not significant.
* $P < .05$.
** $P < .01$.
*** $P < .001$.
**** $P < .0001$.

of corresponding age exceed unity (1.12 and 1.19, respectively; only the latter is significant [$P < .01$]). Since no Rh effects would be expected until higher pregnancy orders, and thus older maternal ages, no O/AB ratio difference between Rh-negative mothers and Rh-positive mothers would be likely at younger maternal ages; and, in fact, this is what is observed. Thus, although the F.D.I.'s based on pooled gestational ages do not affirm conclusively, they do suggest that ABO incompatibility has an effect (either more favorable or less unfavorable than ABO compatibility) on fetal loss in Rh-incompatible mothers.

To examine the second aspect of the ABO-Rh interaction, a similar rationale can be used: the ratio of F.D.I.'s of O Rh-negative to O Rh-positive mothers representing the interaction effect with the comparison Rh−/Rh+ ratio for AB mothers to indicate the simple effect of Rh incompatibility in the absence of ABO incompatibility (i.e., O−/O+ compared to AB−/AB+). Based on total fetal deaths, Rh incompatibility does not seem to decrease the risk of fetal loss in any ABO type, incompatible or compatible (Table 9). Excluding younger mothers, the Rh−/Rh+ ratios exceed 1.0 for every ABO type, reaching statistical significance not only for

older AB mothers but also for some ABO-incompatible types in other maternal age groups. Thus, total F.D.I.'s (i.e., F.D.I.'s based on pooled gestational ages) do not indicate a favorable effect of Rh incompatibility on ABO selection.

In view of the difference between ABO and Rh incompatibility in time of manifestation of selection, however, total fetal deaths are probably not as sensitive an indicator of an ABO-Rh interaction as fetal deaths classified by gestational age. Models of the two possible types of interaction are presented in Table 10, in which the assumptions that Rh loss is manifest in late fetal deaths and ABO loss in early fetal deaths are used as a basis for the critical test ratios. The proposed models are as follows: interaction hypothesis (1) postulates that if ABO incompatibility decreases, or ABO compatibility increases, Rh loss, then the ratio of F.D.I.'s O−/AB− for late fetal deaths will be below unity; interaction hypothesis (2) postulates that if

TABLE 10

INTERACTION HYPOTHESES: MODELS OF ABO-RH INTERACTION AND RESULTANT EXPECTANCIES

Assumptions

ABO-incompatibility selection manifests in early fetal deaths, not late fetal deaths
Rh-incompatibility selection manifests in late fetal deaths, not early fetal deaths

Ratio of F.D.I.'s O/AB (maintaining constant Rh type)=a measure of ABO effect
Ratio of F.D.I.'s Rh−/Rh+ (maintaining constant ABO type)=a measure of Rh effect

Interaction Models and Expectancies for Each

Interaction Hypothesis (1):
If ABO incompatibility protects against manifestation of Rh-incompatibility selection (loss) and/or AB compatibility increases the risk of Rh-incompatibility selection (loss):
Ratio of F.D.I.'s O/AB for late fetal deaths to Rh-negative mothers < 1.0
Ratio of F.D.I.'s O/AB for late fetal deaths to Rh-positive mothers ≥ 1.0

Interaction Hypothesis (2):
If Rh-incompatibility protects against manifestation of the ABO-incompatibility selection (loss) and/or Rh-compatibility increases the risk of ABO-incompatibility selection (loss):
Ratio of F.D.I.'s Rh−/Rh+ for early fetal deaths to O mothers < 1.0
Ratio of F.D.I.'s Rh−/Rh+ for early fetal deaths to AB mothers ≥ 1.0

NOTE.—Hypotheses (1) and (2) are not mutually exclusive.

Rh incompatibility decreases, or Rh compatibility increases, ABO loss, then the ratio of F.D.I.'s O−/O+ for early fetal deaths will be below unity. Moreover, the two hypotheses are not mutually exclusive.

To examine interaction hypothesis (1), the test ratio O−/AB− based on indices of late fetal deaths is compared with the corresponding O+/AB+ ratio. Table 11 shows that there is a significant reduction in late fetal deaths (O−/AB− = .51, $P < .01$) associated with ABO incompatibility in Rh-negative mothers 30 years of age and older. Even for mothers of pooled ages, which includes many younger mothers not yet exposed to risk of prior Rh sensitization, the O/AB ratio for Rh-negative women is still 27% below unity, although the difference does not reach statistical significance. In contrast is the absence of any relative advantage of ABO incompatibility in the comparison group of Rh-positive (Rh-compatible) mothers of corre-

sponding age. Thus, there appears to be support for interaction hypothesis (1), particularly in older Rh-negative mothers who would be subject to the major Rh risk.

As a test for interaction hypothesis (2), the ratio O−/O+ based on early fetal deaths is compared with the corresponding AB−/AB+ ratio (Table 12). With Rh incompatibility there is a significant decrease in risk of early fetal death to O mothers over 30 years of age (O−/O+ = .86; $P < .05$), while the comparison ratio in ABO-compatible AB mothers shows no significant difference in risk of early fetal death (AB−/AB+ = 1.1).† These findings suggest a possible influence of Rh incompatibility on ABO selection not detectable when fetal deaths of all gestational ages are considered.

Although only late fetal deaths provide the critical test ratio of interaction hypothesis (1), and early fetal deaths, interaction hypothesis (2), for completeness the O/AB and Rh−/Rh+ ratios are presented for both early and late fetal deaths (Tables 11

TABLE 11

ABO-RH INTERACTION: O/AB RATIOS BASED ON EARLY AND LATE FETAL DEATH INDICES IN RH-NEGATIVE AND RH-POSITIVE WHITE MOTHERS

	All Ages	30+	<30	25+	<25
Early fetal death:					
Rh−	1.12 N.S.	0.89 N.S.	1.28 N.S.	0.96 N.S.	2.00 N.S.
Rh+	1.27***	1.15 N.S.	1.42****	1.28***	1.27 N.S.
All mothers	1.24***	1.10 N.S.	1.38****	1.22**	1.33*
Late fetal death:					
Rh−	0.73 N.S.	0.51**	1.01 N.S.	0.68 N.S.	0.88 N.S.
Rh+	0.97 N.S.	1.02 N.S.	0.94 N.S.	1.02 N.S.	0.85 N.S.
All mothers	0.92 N.S.	0.89 N.S.	0.95 N.S.	0.95 N.S.	0.86 N.S.

NOTE.—N.S. = not significant.
* $P < .05$.
** $P < .01$.
*** $P < .001$.
**** $P < .0001$.

and 12). Among these additional ratios which do not serve as criteria for the hypotheses there are a few differences that reach levels of statistical significance: high O/AB ratios for early fetal deaths to Rh-positive mothers and those of pooled types (Table 11) and high Rh−/Rh+ ratios for late fetal deaths (Table 12). The interpre-

† It should be noted that on the basis of the a priori hypothesis models presented in Table 10, only the Rh−/Rh+ ratios for early fetal loss to O mothers would be postulated to be significantly below unity; and, in view of observations in this and previous investigations that Rh effects are expected only in multiparous women, the effect would be expected primarily in older rather than younger mothers. Thus, the ratio most likely to be significantly below unity is O−/O+ for early fetal death in the oldest maternal age group (30+). The model specifies further that no such difference would be expected in ABO-compatible mothers. The predicted pattern is precisely what is observed: (1) the only ratio reaching statistical significance is that for O−/O+ early F.D.I.'s in mothers over 30; (2) the other maternal age groups where a less pronounced effect is expected on the basis of theory show O−/O+ early F.D.I. ratios numerically, but not significantly, below 1.0; and (3) as hypothesized, AB−/AB+ early F.D.I. ratios are not significantly below, but fluctuate randomly about, unity. Thus, the one deviation significantly below unity in the absence of others as observed here represents a pattern predicted by, and consistent with, an a priori model and, in biological interpretation, should not be subjected to the blanket statistical criterion of one randomly expected "statistically significant" value obtained at the 5% level when 20 tests are performed.

tation of these significant differences will be considered along with the discussion of the findings and their implications.

DISCUSSION

Until examination of the New York City data (Newcombe, 1963) there was a paucity of information on direct risk of fetal wastage derived from recorded fetal deaths in a total population. Despite the extensive literature, many published studies reached their conclusions concerning the selection of ABO incompatibility and Rh incompatibility only by inference from the computed deficiency of offspring associated with specific parental blood type(s) in collected case reports, or in selected study groups ascertained on the basis of blood type, institution, or pathology. With data derived from all live birth and fetal death records and with adequate numbers, there is an unusual opportunity to clarify the mode of action of ABO incompatibility

TABLE 12

ABO-RH INTERACTION: RH−/RH+ RATIOS BASED ON EARLY AND LATE FETAL DEATH INDICES IN O AND AB WHITE MOTHERS

	All Ages	30+	<30	25+	<25
Early fetal death:					
O	0.92 N.S.	0.86*	0.97 N.S.	0.92 N.S.	0.94 N.S.
AB	1.04 N.S.	1.10 N.S.	1.07 N.S.	1.22 N.S.	0.59 N.S.
All ABO	0.96 N.S.	0.96 N.S.	0.96 N.S.	0.96 N.S.	0.94 N.S.
Late fetal death:					
O	1.52****	1.60****	1.45****	1.63****	1.24 N.S.
AB	2.03***	3.22****	1.35 N.S.	2.44****	1.21 N.S.
All ABO	1.53****	1.64****	1.44****	1.62****	1.26**

NOTE.—N.S. = not significant.
* $P < .05$.
** $P < .01$.
*** $P < .001$.
**** $P < .0001$.

and Rh incompatibility singly and in combination. Certainly, the value of utilizing vital records for research investigations has been made quite apparent.

Yet, caution is required in utilizing vital record data, for problems arise from the nature of the observations themselves as well as the selection of suitable criteria and indices. First, it is necessary to use all fetal deaths and not fetal loss attributable to blood groups alone, since blood group effects cannot be separated from other biological and extrinsic causes of fetal loss. Moreover, even with "cause of death" data, attempts at delineation would not be feasible at this time, for it has been pointed out that wherever objective clinical evidence of an effect of blood groups as contributing to a particular death is not obtainable by present laboratory tests, medical opinions on the matter may be more misleading than helpful. Thus, in such circumstances the best evidence will be of a statistical nature. Second, birth certificates and fetal death records are limited in the quantity and quality of medical, family, and socioeconomic information concerning mothers and infants. Not only are paternal blood types not available, but it is also not possible to link records for individual mothers (i.e., for mothers with several births during the 1954–1959 period). Since no provisions for certificate linkage were established, mothers are counted independently for each live

birth and/or fetal death, rather than as individual mothers with a specific number of live births and/or fetal deaths during the time period.

Third, a typical dilemma in using the vital records is the choice of appropriate maternal subclassifications for the study of incompatibility effects. It is well established that the negative selection of Rh incompatibility manifests itself only after isoimmunization, which would usually occur as a result of previous sensitizing pregnancies. Thus, the only meaningful study group for Rh effects are multiparous mothers. However, birth records are less complete and less likely to be accurate for parity than for maternal ages. Therefore, maternal age, rather than parity, is used in the analysis. Even with this compromise, there is still the decision as to whether older mothers should be used for one analysis (Rh incompatibility) and another maternal age group for the other (ABO incompatibility). If so, which of these age groups should be considered in examining the ABO-Rh interaction?

A further difficulty stems from the complexity of the problem itself. The identification of the components of any interaction, especially two selective forces, is at best a precarious undertaking, and ABO-Rh interaction is no exception. The establishment of suitable indices for each component, excluding the others, is not readily accomplished. The situation is compounded not only by the fact already indicated that the available F.D.I.'s necessarily, and perhaps preferably, include deaths from all causes rather than merely blood group effects, but also by the nature of the ABO-Rh interaction itself, which doubtless involves numerous interdependent relationships of its component parts.

It is therefore particularly noteworthy that even without resolving these methodological problems it is possible to confirm certain distinct and unequivocal patterns, as well as to suggest others which provide a basis for further study.

Consistent with previous reports, the present observations indicate that either ABO incompatibility (Figs. 1 and 2) or Rh incompatibility (Fig. 3), as a single system incompatibility, that is, each in the absence of the other, significantly increases the risk of total fetal loss in white mothers. These findings are conclusive for white mothers, while the observations in Negro mothers are unlike the results for white mothers of this series or those reported in any other study.

Even the higher frequency of D^u type in Negroes and a possible arbitrary classification—or misclassification—of D^u type in Negro mothers could not be responsible for significantly lower fetal loss rates in the maternal category "Rh-negative" as compared to "Rh-positive." Whereas D^u mothers would be less likely to produce anti-D than true Rh-negatives, their risk would be greater than for Rh-positives who are not at all at risk of Rh-sensitization.

Nor can the unexpected Rh findings in Negro mothers be accounted for by maternal age variation, previous history of fetal loss, or the only available index of socioeconomic status—attendant at delivery. Examination of these possible sources of distortion in patterns of fetal wastage fails to reveal any differences between Rh-positive and Rh-negative Negro mothers that might conceal Rh selection by disproportionately altering their respective fetal death indices.

While there still remain many as yet unexplored medical, socioeconomic, and undetectable extrinsic and intrinsic variables which could influence the reporting or mask the blood-group effects in other ways, is it not also possible that the Negro-

white differences, at least for the Rh effect, may not be artifactual but may have a biological, or even a genetic, basis? Case reports have suggested a weaker Rh effect in Negroes than in whites. A comparison study of Rh_o (D) hemolytic disease in Negro and white infants (Molthan, 1963) showed lower morbidity rates for this condition among Negro infants. Moreover, Worlledge (1966) recently reported a deficiency of anti-D production, at least during pregnancy, although in this Nigerian series the so-called naturally occurring antibodies were common and the frequency of anti-Lewis was similar to that in Britain. In addition, Hertzog and Johnston (1968) have suggested positive genetic selection for Rh-negatives in a study of selective mechanisms that act on the Rh polymorphism in American Negroes. They presented empirical data which agreed with their hypothetical model postulating a strong and hitherto undemonstrated selection favoring an Rh-negative gene complex and offsetting the effects of incompatibility selection. Such positive selection pressures, if sufficiently large and advantageous, could counterbalance and override a very weak negative selection against Rh-incompatible progeny. Thus, one possibility is that there is a heterozygote advantage for the Rh−/Rh+ fetus (Woolf, 1956–1957*a*) which in Rh-negative white mothers is counteracted by a high Rh-isoimmunization pressure but in Rh-negative Negro mothers is not completely counteracted by their relatively lower susceptibility to Rh sensitization. Another possibility is that a favorable Rh-negative selection pressure may be peculiar to American Negroes as a result of a shift in their equilibrium values caused by genetic intermixture and environmental change.

Unfortunately, there appear to be no well-documented investigations of incompatibility effects in any sizable series of African or American Negroes comparable to those of white mothers. The questions thus remain as to whether the Negro differences found in the New York data are real or spurious and, if real, whether they are genetically determined or extrinsically caused—possibly even the result of biases in the reporting of live births and fetal deaths. Further investigation of these relationships is required. Hopefully, such studies would elucidate not only the factors underlying the observed Negro differences but also the basic mode of action of incompatibility effects in all groups. Until such additional data are available, any explanation must be considered speculative. For the present, therefore, the inconsistent findings for Negroes necessitate limiting the detailed analysis to data on white mothers.

Probably the most striking observation of this study is the marked difference between ABO and Rh incompatibility in time of occurrence of fetal wastage in white mothers. Among white mothers, ABO incompatibility in the absence of Rh incompatibility is associated with a marked increase (15%–42%) in early fetal deaths without any increase in late fetal loss, and Rh incompatibility in the absence of ABO-incompatibility shows up to a threefold increase in late fetal deaths, without any appreciable effect on fetal loss at early gestational stages.

While the concept of differences in time and mode of action of the two incompatibilities is not new, the supporting evidence has been meager. Many years ago it was suggested (Brambell *et al.*, 1951; Waterhouse and Hogben, 1947) that loss due to ABO incompatibility may occur prior to the recognition of pregnancy. Matsunaga and

Hiraizumi (Matsunaga, 1962; Matsunaga and Hiraizumi, 1962) even proposed gametic selection, sometimes referred to as "meiotic drive," although in 1964 Hiraizumi indicated that the conclusions are not certain. While meiotic drive cannot be ruled out, the methods of measurement utilized, such as "family size equivalents," do not distinguish between prezygotic and postzygotic selection. A deficiency of live births of a particular type can merely indicate that selection has taken place, but cannot detect whether it occurred prior to, or immediately following, syngamy; and statistical analysis of fetal mortality, by definition, represents postzygotic loss. Only some method of determining the genetic composition of spermatozoa and the relative frequency of A-, B-, and O-bearing sperm during development, or at least at maturation and conception, could resolve this problem. Thus far, the immunogenetic studies of spermatozoa (Landsteiner and Levine, 1926; Gullbring, 1957; Shahani and Southam, 1962), which originally held promises of clarifying the issue, have been unsatisfactory and, possibly, invalid (Weil and Rodenburg, 1960; Edwards *et al.*, 1964; Boettcher, 1965). Therefore, until a specific confirmation of meiotic drive is available, early postzygotic selection would seem a more reasonable explanation for the computed deficiency of ABO-incompatible types.

The evidence for early fetal loss in ABO incompatibility was reviewed by Levene and Rosenfield (1961). Based on the percentage of ABO-incompatible mothers among habitual aborters in nine separate series, "an over-all tendency for ABO-incompatibility to increase the risk of abortion" was suggested. This statement was a qualified one because of the significant heterogeneity of data. With regard to maternal-fetal incompatibility occurring in late pregnancy or neonatal life as erythroblastosis, it was concluded that "although serious as a health problem, ABO erythroblastosis does not represent a serious fetal loss from the biological point of view . . . [while] . . . evidence of many kinds shows a much larger and biologically important loss of possible incompatible children"—that is, loss of concepti early in pregnancy.

In contrast, Rh incompatibility entails a much higher risk of erythroblastosis than ABO incompatibility. Since the original report of Levine and Stetson in 1939 and the series of papers following (Levine, Burnham, Katzin, and Vogel, 1941; Levine, Katzin, and Burnham, 1941; Levine, Vogel, Katzin, and Burnham, 1941) identified erythroblastosis fetalis as a consequence of maternal-fetal incompatibility, its association with Rh isoimmunization has been confirmed repeatedly (see Race and Sanger, 1962). Some estimates indicate that over 90% of all erythroblastosis results from Rh_0 (D) incompatibility (Boorman and Dodd, 1961). Moreover, there is no substantial evidence for an increase in early fetal death resulting from Rh incompatibility. Several investigators (Overstreet *et al.*, 1947; Glass, 1949) have pointed to the absence of increased spontaneous abortion rates in Rh-negative women. From these and other reports, the following inferences were formulated as a basis for the proposed models of "the preferential shift" in ABO distribution caused by the interaction of the two systems (Cohen, 1960): (1) ABO incompatibility manifests its deleterious effects primarily in early pregnancy (Waterhouse and Hogben, 1947; Brambell *et al.*, 1951; Matsunaga, 1955, 1956; Matsunaga and Itoh, 1958), while ABO-hemolytic disease is so rare (one in 1,100 pregnancies) that it need not be considered in comparison with the early ABO effect (one in 25 pregnancies); and (2) Rh

incompatibility manifests its harmful effects in late pregnancy and early neonatal life but not at all in the first half of pregnancy (Levine and co-workers, 1941; Overstreet *et al.*, 1947; Glass, 1949).

The New York City data have at last made it possible to document the different effects of ABO incompatibility and Rh incompatibility by actual examination of the relative frequency of early and late fetal deaths derived from population data unselected for blood type or pregnancy history.

Possibly the most complex aspect of ABO and Rh incompatibilities is their effect in combination. Although it is clear that in white mothers, single incompatibility in either of the two systems, ABO or Rh, leads to a higher risk of fetal death, the effect of combined incompatibility in both systems has been opened for reconsideration. An interaction between the two systems, often described as a "protective action of ABO-incompatibility against Rh-incompatibility," was originally postulated by Levine (1943) and has been accepted from evidence in several studies (Van Loghem and Spaander, 1948; Witebsky, 1948; Malone, 1949; Brendemoen, 1952; Nevanlinna, 1952, 1953; Grubb and Sjöstedt, 1955; Heistö, 1955; Woolf, 1956–7*b;* Levine, 1958, 1959; Cohen and Glass, 1959; Cohen, 1960; Andersen *et al.*, 1961; Race and Sanger, 1962; Kelly and Jacobs, 1963; Donohue and Wake, 1964; Cooke *et al.*, 1965; Knox, 1965*a*, 1965*b*; Murray *et al.*, 1965). Recently, however, Newcombe (1963) suggested that "the risk of fetal death is correlated with the number of antigenically active ABO and Rh alleles unrepresented in the mothers' genotype. . . . Only the AB Rh-negative blood type fails to fit neatly into the scheme so as to appear as a special case." Such a relationship implies a simple additivity of ABO and Rh incompatibility effects.

Therefore, the alternative interpretations, interaction or "protective action" and "additivity" of various types, are examined in the present data. In this study, however, AB Rh-negative mothers are not excluded from the evaluation of ABO and Rh effects, since AB Rh-negative mothers are the only group with simple Rh incompatibility in the absence of ABO incompatibility.

Clearly, the findings fail to indicate simple additivity of ABO and Rh incompatibility effects. First, in every mode of comparison, regardless of maternal age or whether total fetal deaths or fetal deaths classified by length of gestation are considered, the numerical F.D.I. for the "two system incompatibles" falls below, although not significantly below, the F.D.I. for one or the other type of "single system incompatible" mothers, thus rejecting additivity hypothesis (1). Second, no positive relationship appears between the observed F.D.I.'s and (i) the total number of missing antigens in both systems (additivity hypothesis [2]), or (ii) the expected proportion of incompatible children summing expected incompatibles in ABO, Rh, and combined systems (additivity hypothesis [3]), or (iii) the expected proportion of ABO incompatibles in Rh-negative mothers only (additivity hypothesis [4]).

Consequently, some other type of relationship of the two systems is suggested, such as a buffering action whereby incompatibility in both systems is less deleterious than in only one system, as suggested by Grubb and Sjöstedt (1955) and other investigators following Levine's original proposal (1943). Unfortunately, the mechanism of a nonadditive interaction is not so readily demonstrated as its existence. The simplest types to be considered are: (1) a favorable influence of ABO incompati-

bility decreasing the selective loss of Rh incompatibility or an unfavorable effect of ABO compatibility increasing the selective loss of Rh incompatibility (interaction hypothesis [1]), (2) a favorable effect of Rh incompatibility decreasing, or an unfavorable effect of Rh compatibility increasing, the selective loss of ABO incompatibility (interaction hypothesis [2]), or (3) a combination of (1) and (2).

Examined in terms of total fetal deaths and fetal deaths at critical gestational stages, the specific test ratios tend to support both interaction hypotheses (1) and (2). Whatever the specific mechanism of the interaction may be, it is clear that double incompatibility affords a lower risk of Rh selection in terms of late fetal loss than Rh incompatibility alone and, possibly, also a lower risk of ABO selection in terms of early fetal loss than ABO incompatibility alone.

Moreover, the few significant deviations in the data other than those specified by the hypotheses are not inconsistent with them. The significantly greater early fetal wastage to O as compared to AB mothers among Rh-positive mothers and mothers of pooled Rh types (Table 11) clearly involves the effect of ABO incompatibility in the absence of Rh incompatibility—that is, simple ABO loss not associated with the combined effects of the two systems. Similarly, the significantly high Rh−/Rh+ ratios for late fetal deaths to both ABO-compatible and ABO-incompatible mothers represent simple Rh loss (Table 12). The fact that these high ratios occur in ABO-incompatible mothers as well as in ABO-compatible mothers suggests that Rh incompatibility tends to manifest a selective effect in *all* ABO types, although it appears less marked in ABO incompatibles due to the interaction. The findings agree with the recent observations of Vos (1966) and his view that, although ABO incompatibility affords some protection against Rh selection, the protection is apparently not absolute.

At present, however, only the qualitative existence of the ABO-Rh interaction and the likelihood of its diphasic nature can be demonstrated and no quantitative estimates are feasible. While the evidence supports both types of interactions, it does not imply that they are equal in magnitude. The ultimate impact of both incompatibilities remains a function of the magnitudes of the simple ABO and Rh effects as well as the interaction effects. These in turn depend on the population distribution of ABO and Rh types and on the extrinsic, genetic, and other biological factors that determine maternal antibody response, placental permeability, and all the maternal-fetal factors influencing the effects of maternal immunization status on the fetus. Unfortunately, it is not yet possible to adjust sufficiently for these parameters to estimate the degree of individual effects and/or interaction. For this reason also fiducial limits on the risk ratios, although computed, are not presented; rather, the ratios are discussed in terms of whether they are significantly above or below unity.

Nevertheless, inability to assign quantitative values to the ABO-Rh interaction and its components does not preclude consideration of possible etiological mechanisms. The suggestion of the diphasic nature of ABO-Rh interaction makes it necessary to reconsider previous interpretations of ABO-Rh interaction and the concomitant biological mechanisms. In the 25 years since a protective action of ABO incompatibility against Rh selection was suggested by Levine (1943) and reaffirmed in numerous subsequent reports, various biological explanations of this interaction have been proposed. These have been reviewed elsewhere (Mollison *et al.*, 1952;

Cohen, 1960; Race and Sanger, 1962). The competition between antigens (Wiener, 1945) and the rapid destruction of ABO-incompatible fetal erythrocytes in the maternal circulation by the maternal anti-A and/or anti-B normally present (Mollison, 1952; Race, 1952; Reepmaker, 1955; Levine, 1958; Race and Sanger, 1962; Weiner and Battey, 1962) "provide two possible mechanisms." These are not mutually exclusive, and "a third alternative is that both are valid, that the influence of ABO incompatibility may itself be mediated in more than one way, and that quantitative effects need to be considered" (Cohen, 1960).

Unlike the long-standing hypothesis of an effect of ABO incompatibility on Rh selection, an effect of Rh incompatibility on ABO selection has not been considered per se in previous reports of ABO-Rh interaction and was merely implied by Grubb and Sjöstedt (1955) in their study of abortion and sterility and by Bresler (1964) in his study of postnatal mortality. If confirmed, this second aspect of interaction cannot be attributed, as can the first, to elimination from the maternal circulation of ABO-incompatible, Rh-incompatible erythrocytes prior to their stimulation of maternal antibody-producing tissues. On the other hand, it is not inconsistent with the concept of competition of antigens (Wiener, 1945); Murray's suggestion of an association among maternal ABO type, differences in saline/incomplete anti-Rh relationships, and the severity of hemolytic disease (1967); and the biological basis of the effect of ABO incompatibility against Rh selection recently proposed by Vos (1966). Vos states that "the maternal antibody forming mechanism being confronted to produce two different types of antibodies (anti-A or anti-B, which are generally associated with hemolysin production, and anti-Rh, which is not) may do so, but with the loss of the ability to form high titred Rh antibodies."

Experimental evidence for this mechanism has been presented recently: Stern (1965), after a study of rats immunized with sheep erythrocytes, concluded that "significant suppression of antibody production can result from double incompatibilities." It is, therefore, quite reasonable that in a human host, similarly, some antibody suppression may result from exposure to fetal erythrocytes with more than one incompatible antigen. If this is the underlying biological mechanism of interaction hypothesis (1), then would not the same mechanism, which is postulated to be responsible for keeping the anti-Rh titer low, also tend to buffer the anti-A and/or anti-B titers so that their levels are not so high in mothers who are both ABO incompatible and Rh incompatible, as in mothers who are ABO incompatible but Rh compatible?

The observations concerning maternal age at manifestation lend further support to this interpretation. It appears that any more favorable influence of Rh incompatibility or less favorable influence of Rh compatibility against the effect of ABO incompatibility is detectable in older mothers rather than younger mothers (Table 12), suggesting that the difference may result from previous challenge to the antibody-forming organs by Rh-incompatible cells leading to the depression of anti-A and/or anti-B titers. However, although the impact of suppressed anti-A and/or anti-B may indeed reduce ABO loss in O Rh-negative mothers, especially in terms of Rh-negative as compared to Rh-positive, it is puzzling how this "loss" can decrease below the values for AB Rh-negative mothers when only early (and thus non-Rh deaths) are involved (Table 11).

In conclusion, it is now apparent that the manifestation of ABO incompatibility, Rh incompatibility, and the interaction of the two incompatibilities are far more complex than previously recognized, even though they follow patterns that are statistically discernible and, at least in part, biologically explicable. While not every aspect of ABO and Rh incompatibility considered here has been completely clarified, the data analyzed have yielded some interesting results to confirm previous reports of ABO and Rh effects in terms of both total fetal wastage and the occurrence of fetal deaths at different gestational periods. They have, in addition, provided a framework of reference for other studies concerning the possible impact of racial—perhaps sociobiological, perhaps genetic—factors on the effect of ABO and Rh incompatibility, as well as a basis for the further investigation of a facet of ABO-Rh interaction not previously explored. The elucidation of these aspects promises a new insight into the role of blood groups in the risk of fetal deaths.

SUMMARY

I. To clarify the relationship of maternal ABO and Rh types to fetal wastage and to re-evaluate various interpretations of the effect of ABO and Rh incompatibility singly and in combination, a large body of data from the New York City live birth and fetal death records over the years 1954–1959 was studied, including all fetal deaths and a 10% sample of live births occurring during these years. Three aspects were explored: (1) the impact of single system incompatibility on risk of fetal death to white and Negro mothers, (2) differences in gestational age at which fetal deaths occur in ABO incompatibility and Rh incompatibility, and (3) the effect of various combinations of ABO incompatibility and Rh incompatibility on fetal wastage (total, early, and late fetal deaths).

II. The findings concerning single incompatibilities are as follows:

For white mothers the results are consistent with those of previous studies: (1) ABO-incompatible types show a significantly higher risk of fetal loss than those of the ABO-compatible types in both younger and older mothers, and (2) Rh-negative mothers have significantly higher fetal death indices than Rh-positive mothers, whether ABO types are pooled or each ABO type is considered separately and whether all ages are combined or only those over 25 years of age or over 30 years of age are considered, although the differences are most marked in older mothers.

Among Negro mothers, there is no clear pattern of ABO-incompatibility manifestation similar to that in white mothers of this series or in previously published series. Nor is there any evidence for negative selection associated with Rh incompatibility; in fact, Rh-positive (Rh-compatible) mothers have significantly more fetal loss than Rh-negatives (potentially Rh-incompatible types). Since these unusual findings in Negro mothers remain as yet unexplained on the basis of maternal age variation, prior history of fetal loss, or any detectable socioeconomic factors, the detailed analysis of the data with regard to ABO-Rh interaction and gestational age of manifestation of the effects of incompatibility has been limited to white mothers.

III. There is a marked difference between ABO and Rh incompatibility in time of occurrence of fetal wastage in white mothers, each system revealing a distinct and discernibly different pattern of selection. ABO incompatibility in the absence of Rh incompatibility is associated with a significant increase in early fetal deaths (15%–

42%) without any increase in late fetal loss, whereas Rh incompatibility in the absence of ABO incompatibility manifests in as much as a threefold increase in late fetal deaths without any effect on fetal loss at early gestational ages.

IV. The effect of ABO and Rh incompatibility in combination is examined here in respect to four additivity hypotheses as well as various interaction hypotheses. The observations clearly do not indicate simple additivity of ABO and Rh incompatibility effects on the basis of any facets of additivity explored, whereas there is support for each of the interaction hypotheses, especially when based on the critical test ratios utilizing fetal deaths subclassified by gestational age at occurrence; that is, there appears to be an effect of ABO compatibility status on Rh incompatibility effects and possibly also an effect of Rh compatibility status on ABO incompatibility effects. Thus, it seems that the manifestations of the two incompatibilities and their interactions are more complex than previously recognized.

Whatever the details of the interaction may be, it is nevertheless clear that double incompatibility (ABO and Rh) affords a lower risk of Rh selection in terms of late fetal loss than Rh incompatibility alone and, possibly, also a lower risk of ABO selection in terms of early fetal loss than ABO incompatibility alone. Since it is not yet possible to adjust sufficiently for the numerous parameters—intrinsic and extrinsic—involved in the interactions, only their qualitative existence can be demonstrated and no quantitative estimates are feasible.

V. The possible impact of racial factors—perhaps sociobiological, perhaps genetic—on the effect of ABO and Rh incompatibility and the suggestion of a previously unexplored facet of ABO-Rh interaction provide new areas for further study.

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APPENDIX A—TABLE A1—AGE DISTRIBUTION FOR WHITE AND NEGRO MOTHERS BY ABO TYPE (1954–1959)

Age Group of Mother	Whites										Negroes									
	O	%	A	%	B	%	AB	%	Total	%	O	%	A	%	B	%	AB	%	Total	%
<20:																				
L.B.	2,115	5.84	1,592	5.70	523	5.67	160	5.13	4,390	5.74	1,215	15.44	610	15.53	484	15.58	69	11.88	2,378	15.36
F.D.	627	3.58	463	3.71	164	4.31	43	3.18	1,297	3.69	502	8.11	254	7.74	192	7.92	49	9.14	997	8.02
F.D.I.	2.96		2.91		3.14		2.69		2.95		4.13		4.16		3.97		7.10		4.19	
Reprod.	21,777	5.73	16,383	5.61	5,394	5.62	1,643	5.04	45,197	5.65	12,652	14.91	6,354	14.93	5,032	15.02	739	11.65	24,777	14.81
20–24:																				
L.B.	10,511	29.01	8,096	28.97	2,604	28.25	855	27.34	22,066	28.84	2,598	33.02	1,310	33.34	1,018	32.76	192	33.05	5,118	33.05
F.D.	3,826	21.86	2,797	22.39	831	21.84	266	19.69	7,720	21.96	1,609	25.99	826	25.18	616	25.42	145	27.05	3,196	25.71
F.D.I.	3.64		3.45		3.19		3.11		3.50		6.19		6.31		6.05		7.55		6.24	
Reprod.	108,936	28.68	83,757	28.68	26,871	28.00	8,816	27.03	228,380	28.53	27,589	32.51	13,926	32.71	10,796	32.23	2,065	32.54	54,376	32.51
25–29:																				
L.B.	11,957	33.00	9,203	32.93	3,061	33.21	1,079	34.51	25,300	33.06	1,982	25.19	1,036	26.37	827	26.62	165	28.40	4,010	25.90
F.D.	5,070	28.97	3,471	27.79	1,094	28.75	410	30.35	10,045	28.58	1,794	28.97	997	30.40	721	29.76	136	25.37	3,648	29.35
F.D.I.	4.24		3.77		3.57		3.80		3.97		9.05		9.62		8.72		8.24		9.10	
Reprod.	124,640	32.82	95,501	32.71	31,704	33.03	11,200	34.33	263,045	32.87	21,614	25.47	11,357	26.68	8,991	26.84	1,786	28.14	43,748	26.15
30–39:																				
L.B.	10,817	29.86	8,470	30.30	2,842	30.83	970	31.02	23,099	30.19	1,956	24.86	919	23.39	734	23.62	151	25.99	3,760	24.28
F.D.	6,920	39.54	4,916	39.36	1,491	39.19	551	40.78	13,878	39.48	2,090	33.75	1,109	33.81	834	34.42	191	35.63	4,224	33.98
F.D.I.	6.40		5.80		5.25		5.68		6.01		10.69		12.07		11.36		12.65		11.23	
Reprod.	115,090	30.30	89,616	30.69	29,911	31.17	10,251	31.42	244,868	30.59	21,650	25.51	10,299	24.19	8,174	24.41	1,701	26.80	41,824	25.01
40–49:																				
L.B.	828	2.29	589	2.11	187	2.03	63	2.01	1,667	2.18	116	1.47	54	1.38	44	1.42	4	0.69	218	1.41
F.D.	1,060	6.06	843	6.75	225	5.91	81	6.00	2,209	6.28	197	3.18	94	2.87	60	2.48	15	2.80	366	2.94
F.D.I.	12.80		14.31		12.03		12.86		13.25		16.98		17.41		13.64		37.50		16.79	
Reprod.	9,340	2.46	6,733	2.31	2,095	2.18	711	2.18	18,879	2.36	1,357	1.60	634	1.49	500	1.49	55	0.87	2,546	1.52
Total:																				
L.B.	36,228	100.00	27,950	100.01	9,217	99.99	3,127	100.01	76,522	100.01	7,867	99.98	3,929	100.01	3,107	100.00	581	100.01	15,484	100.00
F.D.	17,503	100.01	12,490	100.00	3,805	100.00	1,351	100.00	35,149	99.99	6,192	100.00	3,280	100.00	2,423	100.00	536	99.99	12,431	100.00
F.D.I.	4.83		4.47		4.13		4.32		4.59		7.87		8.35		7.80		9.23		8.03	
Reprod.	379,783	99.99	291,990	100.00	95,975	100.00	32,621	100.00	800,369	100.00	84,862	100.00	42,570	100.00	33,493	99.99	6,346	100.00	167,271	100.00
Age rejects:																				
L.B.	2	.....	5	.....	3	.....	0	.....	10	.....	0	.....	3	.....	2	.....	0	.....	5	.....
F.D.	72	.....	35	.....	16	.....	6	.....	129	.....	34	.....	15	.....	12	.....	0	.....	61	.....
Total including age rejects:																				
L.B.	36,230	.....	27,955	.....	9,220	.....	3,127	.....	76,532	.....	7,867	.....	3,932	.....	3,109	.....	581	.....	15,489	.....
F.D.	17,575	.....	12,525	.....	3,821	.....	1,357	.....	35,278	.....	6,226	.....	3,295	.....	2,435	.....	536	.....	12,492	.....
F.D.I.	4.85		4.48		4.14		4.34		4.61		7.91		8.38		7.83		9.23		8.07	
Reprod.	379,875	.....	292,075	.....	96,021	.....	32,627	.....	800,598	.....	84,896	.....	42,615	.....	33,525	.....	6,346	.....	167,382	.....

NOTE.—Reprod. = estimate of reproduction derived from sum of total fetal deaths (F.D.) and 10 × live births (L.B.), since L.B. here represents a 10% sample of all live births.

APPENDIX A—TABLE A2

ABO Distribution of White and Negro Mothers by Age Group (1954–1959)

Blood Type of Mother	30+		<30		25+		<25	
	N	%	*N*	%	*N*	%	*N*	%
	Whites							
O:								
L.B.	11,645	47.02	24,583	47.50	23,602	47.14	12,626	47.72
F.D.	7,980	49.61	9,523	49.96	13,050	49.94	4,453	49.38
F.D.I.	6.85		3.87		5.53		3.53	
A:								
L.B.	9,059	36.58	18,891	36.50	18,262	36.48	9,688	36.62
F.D.	5,759	35.80	6,731	35.31	9,230	35.32	3,260	36.15
F.D.I.	6.36		3.56		5.05		3.36	
B:								
L.B.	3,029	12.23	6,188	11.96	6,090	12.16	3,127	11.82
F.D.	1,716	10.67	2,089	10.96	2,810	10.75	995	11.03
F.D.I.	5.67		3.38		4.61		3.18	
AB:								
L.B.	1,033	4.17	2,094	4.05	2,112	4.22	1,015	3.84
F.D.	632	3.93	719	3.77	1,042	3.99	309	3.43
F.D.I.	6.12		3.43		4.93		3.04	
Total:								
L.B.	24,766	.....	51,756	.....	50,066	.....	26,456	.....
F.D.	16,087	.....	19,062	.....	26,132	.....	9,017	.....
F.D.I.	6.50		3.68		5.22		3.41	
	Negroes							
O:								
L.B.	2,072	52.09	5,795	50.37	4,054	50.75	3,813	50.87
F.D.	2,287	49.83	3,905	49.80	4,081	49.54	2,111	50.35
F.D.I.	11.04		6.74		10.07		5.54	
A:								
L.B.	973	24.46	2,956	25.69	2,009	25.15	1,920	25.61
F.D.	1,203	26.21	2,077	26.49	2,200	26.71	1,080	25.76
F.D.I.	12.36		7.03		10.95		5.63	
B:								
L.B.	778	19.56	2,329	20.24	1,605	20.09	1,502	20.04
F.D.	894	19.48	1,529	19.50	1,615	19.60	808	19.27
F.D.I.	11.49		6.57		10.06		5.38	
AB:								
L.B.	155	3.90	426	3.70	320	4.01	261	3.48
F.D.	206	4.49	342	4.36	342	4.15	206	4.91
F.D.I.	13.29		8.03		10.69		7.89	
Total:								
L.B.	3,978	.....	11,506	.....	7,988	.....	7,496	.....
F.D.	4,590	.....	7,841	.....	8,238	.....	4,193	.....
F.D.I.	11.54		6.81		10.31		5.59	

APPENDIX A—TABLE A3

AGE DISTRIBUTION OF WHITE AND NEGRO MOTHERS BY ABO AND RH TYPES (1954–1956)

MATERNAL AGE	O						A						B						AB						TOTAL					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined		Rh+		Rh−		Combined		Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
	Whites																													
<20:																														
L.B.	892	5.61	114	5.35	1,006	5.58	570	4.65	103	5.73	673	4.79	207	4.97	19	3.49	226	4.80	69	4.97	9	4.84	78	4.95	1,738	5.15	245	5.26	1,983	5.17
F.D.	268	3.55	27	2.44	295	3.41	190	3.46	25	2.96	215	3.39	66	3.97	9	3.01	75	3.82	17	2.97	2	2.04	19	2.84	541	3.54	63	2.68	604	3.43
Reprod.	9,188	5.51	1,167	5.21	10,355	5.48	5,890	4.60	1,055	5.60	6,945	4.73	2,136	4.93	199	3.46	2,335	4.76	707	4.89	92	4.70	799	4.87	17,921	5.08	2,513	5.14	20,434	5.09
20–24:																														
L.B.	4,424	27.80	604	28.37	5,028	27.87	3,467	28.30	478	26.59	3,945	28.08	1,147	27.52	141	25.87	1,288	27.33	360	25.92	56	30.11	416	26.41	9,398	27.87	1,279	27.46	10,667	27.82
F.D.	1,648	21.82	234	21.16	1,882	21.74	1,212	22.04	175	20.73	1,387	21.87	343	20.63	59	19.73	402	20.49	125	21.85	13	13.27	138	20.60	3,328	21.77	481	20.49	3,809	21.60
Reprod.	45,888	27.53	6,274	28.01	52,162	27.59	35,882	28.03	4,955	26.32	40,837	27.81	11,813	27.25	1,469	25.55	13,282	27.06	3,725	25.76	573	29.26	4,298	26.18	97,308	27.61	13,271	27.12	110,579	27.55
25–29:																														
L.B.	5,413	34.02	705	33.11	6,118	33.91	4,121	33.64	629	34.98	4,750	33.81	1,408	33.78	203	37.25	1,611	34.18	492	35.42	67	36.02	559	35.49	11,434	33.91	1,604	34.44	13,038	33.97
F.D.	2,202	29.16	335	30.29	2,537	29.30	1,538	27.97	225	26.66	1,763	27.80	508	30.55	102	34.11	610	31.09	153	26.75	31	31.63	184	27.46	4,401	28.79	693	29.53	5,094	28.89
Reprod.	56,332	33.80	7,385	32.97	63,717	33.70	42,748	33.39	6,515	34.61	49,263	33.55	14,588	33.66	2,132	37.08	16,720	34.06	5,073	35.08	701	35.80	5,744	35.16	118,741	33.69	16,733	34.20	135,474	33.75
30–39:																														
L.B.	4,832	30.37	657	30.86	5,489	30.43	3,825	31.22	547	30.42	4,372	31.12	1,322	31.72	171	31.38	1,493	31.68	445	32.04	52	27.96	497	31.56	10,424	30.91	1,427	30.64	11,851	30.88
F.D.	2,967	39.29	442	39.96	3,409	39.37	2,196	39.94	361	42.77	2,557	40.32	649	39.03	109	36.45	758	38.63	242	42.31	46	46.94	288	42.99	6,054	39.61	958	40.82	7,012	39.77
Reprod.	51,287	30.77	7,012	31.31	58,299	30.84	40,446	31.60	5,831	30.98	46,277	31.52	13,869	32.00	1,819	31.64	15,688	31.96	4,692	32.44	566	28.91	5,258	32.02	110,294	31.29	15,228	31.12	125,522	31.27
40–49:																														
L.B.	350	2.20	49	2.30	399	2.21	268	2.19	41	2.28	309	2.20	84	2.02	11	2.02	95	2.02	23	1.66	2	1.08	25	1.59	725	2.15	103	2.21	828	2.16
F.D.	467	6.18	68	6.15	535	6.18	362	6.58	58	6.87	420	6.62	97	5.83	20	6.69	117	5.96	35	6.12	6	6.12	41	6.12	961	6.29	152	6.48	1,113	6.31
Reprod.	3,967	2.38	558	2.49	4,525	2.39	3,042	2.38	468	2.49	3,510	2.39	937	2.16	130	2.26	1,067	2.17	265	1.83	26	1.33	291	1.77	8,211	2.33	1,182	2.42	9,393	2.34
Total:																														
L.B.	15,911	.....	2,129	.....	18,040	.....	12,251	.....	1,798	.....	14,049	.....	4,168	.....	545	.....	4,713	.....	1,389	.....	186	.....	1,575	.....	33,719	.....	4,658	.....	38,377	.....
F.D.	7,552	.....	1,106	.....	8,658	.....	5,498	.....	844	.....	6,342	.....	1,663	.....	299	.....	1,962	.....	572	.....	98	.....	670	.....	15,285	.....	2,347	.....	17,632	.....
Reprod.	166,662	.....	22,396	.....	189,058	.....	128,008	.....	18,824	.....	146,832	.....	43,343	.....	5,749	.....	49,092	.....	14,462	.....	1,958	.....	16,420	.....	352,475	.....	48,927	.....	401,402	.....
Age rejects:																														
L.B.	1	.....	0	.....	1	.....	1	.....	0	.....	1	.....	1	.....	0	.....	1	.....	0	.....	0	.....	0	.....	3	.....	0	.....	3	.....
F.D.	29	.....	2	.....	31	.....	15	.....	4	.....	19	.....	7	.....	1	.....	8	.....	0	.....	0	.....	0	.....	51	.....	7	.....	58	.....
Total including rejects:																														
L.B.	15,912	.....	2,129	.....	18,041	.....	12,252	.....	1,798	.....	14,050	.....	4,169	.....	545	.....	4,714	.....	1,389	.....	186	.....	1,575	.....	33,722	.....	4,658	.....	38,380	.....
F.D.	7,581	.....	1,108	.....	8,689	.....	5,513	.....	848	.....	6,361	.....	1,670	.....	300	.....	1,970	.....	572	.....	98	.....	670	.....	15,336	.....	2,354	.....	17,690	.....
F.D.I.	4.76	.....	5.20	.....	4.82	.....	4.50	.....	4.72	.....	4.53	.....	4.01	.....	5.50	.....	4.18	.....	4.12	.....	5.27	.....	4.25	.....	4.55	.....	5.05	.....	4.61	.....

NOTE.—L.B. = live births; F.D. = fetal deaths; F.D.I. = fetal death index; Reprod. = (L.B. × 10) + F.D.

APPENDIX A—TABLE A3—*Continued*

Maternal Age	O						A						B						AB						Total					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined		Rh+		Rh−		Combined		Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
	Negroes																													
<20:																														
L.B.	472	14.01	29	11.42	501	13.83	240	14.56	12	9.92	252	14.25	209	16.10	9	8.65	218	15.55	25	9.54	1	4.35	26	9.12	946	14.38	51	10.16	997	14.08
F.D.	192	7.24	12	7.79	204	7.27	87	6.56	14	13.33	101	7.05	78	7.57	7	9.59	85	7.71	17	8.37	1	7.69	18	8.33	374	7.17	34	9.86	408	7.34
Reprod.	4,912	13.52	302	11.21	5,214	13.36	2,487	13.97	134	10.19	2,621	13.71	2,168	15.47	97	8.72	2,265	14.98	267	9.46	11	4.53	278	9.07	9,834	13.85	544	10.14	10,378	13.59
20–24:																														
L.B.	1,049	31.14	94	37.01	1,143	31.55	539	32.71	54	44.63	593	33.52	399	30.74	38	36.54	437	31.17	76	29.01	11	47.83	87	30.53	2,063	31.37	197	39.24	2,260	31.93
F.D.	692	26.08	31	20.13	723	25.76	340	25.62	27	25.71	367	25.63	269	26.12	14	19.18	283	25.66	62	30.54	0	00.00	62	28.70	1,363	26.15	72	20.87	1,435	25.82
Reprod.	11,182	30.77	971	36.04	12,153	31.13	5,730	32.18	567	43.12	6,297	32.93	4,259	30.40	394	35.40	4,653	30.77	822	29.12	110	45.27	932	30.40	21,993	30.98	2,042	38.06	24,035	31.48
25–29:																														
L.B.	930	27.60	52	20.47	982	27.10	451	27.61	25	20.66	480	27.13	351	27.04	23	22.12	374	26.68	82	31.30	4	17.39	86	30.18	1,818	27.64	104	20.72	1,922	27.15
F.D.	794	29.93	55	35.71	849	30.25	412	31.05	33	31.43	445	31.08	317	30.78	27	36.99	344	31.19	48	23.65	6	46.15	54	25.00	1,571	30.14	121	35.07	1,692	30.44
Reprod.	10,094	27.77	575	21.34	10,669	27.33	4,962	27.87	283	21.52	5,245	27.43	3,827	27.32	257	23.09	4,084	27.01	868	30.75	46	18.93	914	29.81	19,751	27.82	1,161	21.64	20,912	27.39
30–39:																														
L.B.	877	26.03	75	29.53	952	26.28	397	24.09	28	23.14	425	24.02	315	24.27	34	32.69	349	24.89	78	29.77	7	30.43	85	29.82	1,667	25.35	144	28.69	1,811	25.58
F.D.	891	33.58	51	33.12	942	33.56	451	33.99	27	25.71	478	33.38	336	32.62	24	32.88	360	32.64	70	34.48	4	30.77	74	34.26	1,748	33.53	106	30.72	1,854	33.36
Reprod.	9,661	26.58	801	29.73	10,462	26.80	4,421	24.83	307	23.35	4,728	24.73	3,486	24.88	364	32.70	3,850	25.46	850	30.11	74	30.45	924	30.14	18,418	25.95	1,546	28.82	19,664	25.76
40–49:																														
L.B.	41	1.22	4	1.57	45	1.24	17	1.03	2	1.65	19	1.07	24	1.85	0	00.00	24	1.71	1	0.38	0	00.00	1	0.35	83	1.26	6	1.20	89	1.26
F.D.	84	3.17	5	3.25	89	3.17	37	2.79	4	3.81	41	2.86	30	2.91	1	1.37	31	2.81	6	2.96	2	15.38	8	3.70	157	3.01	12	3.48	169	3.04
Reprod.	494	1.36	45	1.67	539	1.38	207	1.16	24	1.83	231	1.21	270	1.93	1	0.09	271	1.79	16	0.57	2	0.82	18	0.59	987	1.39	72	1.34	1,059	1.39
Total:																														
L.B.	3,369	.....	254	.....	3,623	.....	1,648	.....	121	.....	1,769	.....	1,298	.....	104	.....	1,402	.....	262	.....	23	.....	285	.....	6,577	.....	502	.....	7,079	.....
F.D.	2,653	.....	154	.....	2,807	.....	1,327	.....	105	.....	1,432	.....	1,030	.....	73	.....	1,103	.....	203	.....	13	.....	216	.....	5,213	.....	345	.....	5,558	.....
Reprod.	36,343	.....	2,694	.....	39,037	.....	17,807	.....	1,315	.....	19,122	.....	14,010	.....	1,113	.....	15,123	.....	2,823	.....	243	.....	3,066	.....	70,983	.....	5,365	.....	76,348	.....
Age rejects:																														
L.B.	0	.....	0	.....	0	.....	1	.....	0	.....	1	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	1	.....	0	.....	1	.....
F.D.	14	.....	1	.....	15	.....	10	.....	0	.....	10	.....	2	.....	0	.....	2	.....	0	.....	0	.....	0	.....	26	.....	1	.....	27	.....
Total including rejects:																														
L.B.	3,369	.....	254	.....	3,623	.....	1,649	.....	121	.....	1,770	.....	1,298	.....	104	.....	1,402	.....	262	.....	23	.....	285	.....	6,578	.....	502	.....	7,080	.....
F.D.	2,667	.....	155	.....	2,822	.....	1,337	.....	105	.....	1,442	.....	1,032	.....	73	.....	1,105	.....	203	.....	13	.....	216	.....	5,239	.....	346	.....	5,585	.....
F.D.I.	7.92	.....	6.10	.....	7.79	.....	8.11	.....	8.68	.....	8.15	.....	7.95	.....	7.02	.....	7.88	.....	7.75	.....	5.65	.....	7.58	.....	7.96	.....	6.89	.....	7.89	.....

APPENDIX A—TABLE A4

DISTRIBUTION OF WHITE AND NEGRO MOTHERS OF LIVE BIRTHS AND FETAL DEATHS BY NUMBER OF PREGNANCIES (1954-1959)

PREGNANCIES (*N*)	WHITES				NEGROES			
	Live Births		Fetal Deaths		Live Births		Fetal Deaths	
	N	%	*N*	%	*N*	%	*N*	%
1	25,122	32.97	7,680	24.10	4,194	27.52	2,019	17.98
2	23,134	30.36	7,706	24.18	3,534	23.19	2,022	18.01
3	14,523	19.06	6,419	20.15	2,667	17.50	2,036	18.13
4–7	12,651	16.60	8,935	28.04	4,246	28.52	4,286	38.17
8–15	768	1.01	1,123	3.52	497	3.26	865	7.70
Total	76,198	.....	31,863	.....	15,238	.....	11,228	.....
Rejects	334	0.44	3,415	9.68	251	1.62	1,264	10.12
Total including rejects	76,532	.....	35,278	.....	15,489	.....	12,492	.....

APPENDIX A—TABLE A5

DISTRIBUTION OF WHITE AND NEGRO MOTHERS OF LIVE BIRTHS AND FETAL DEATHS BY HISTORY OF PRIOR FETAL DEATH (1954–1959)

PRIOR FETAL DEATHS	WHITES				NEGROES			
	Live Births		Fetal Deaths		Live Births		Fetal Deaths	
	N	%	*N*	%	*N*	%	*N*	%
0	65,617	85.74	23,678	67.14	12,353	79.76	7,369	59.00
1–20	10,913	14.26	11,590	32.86	3,135	20.24	5,121	41.00
Total	76,530	.....	35,268	.....	15,488	.....	12,490	.....
Reject	2	0.00	10	0.03	1	0.01	2	0.02
Total including rejects	76,532	.....	35,278	.....	15,489	.....	12,492	.....

APPENDIX A—TABLE A6

DISTRIBUTION OF WHITE AND NEGRO MOTHERS OF LIVE BIRTHS AND FETAL DEATHS BY ATTENDANT AT DELIVERY (1954-1959)

ATTENDANT	WHITES				NEGROES			
	Live Births		Fetal Deaths		Live Births		Fetal Deaths	
	N	%	*N*	%	*N*	%	*N*	%
Private physician at home	100	0.13	313	0.89	10	0.06	21	0.17
Midwife	3	0.00	3	0.01	0	0.00	0	0.00
Lobenstein nurse	34	0.04	2	0.01	5	0.03	0	0.00
Ambulance—home delivery	207	0.27	1,129	3.20	136	0.88	1,824	14.60
Private hospital service	57,185	74.72	24,625	69.80	1,689	10.90	1,307	10.46
General hospital service	18,976	24.79	9,194	26.06	13,626	87.97	9,332	74.70
Ambulance—other known place	19	0.02	2	0.01	21	0.14	2	0.02
Other	8	0.01	10	0.03	2	0.01	6	0.05
Total	76,532	.....	35,278	.....	15,489	.....	12,492	.....

APPENDIX A—TABLE A7

ABO AND RH DISTRIBUTION OF WHITE MOTHERS BY MATERNAL AGE GROUPS FOR TOTAL FETAL DEATHS (1954–1956)

BLOOD TYPE OF MOTHER	OLDER MOTHERS						YOUNGER MOTHERS					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
	Boundary, 30 Years*											
O:												
L.B.	5,182	46.48	706	46.14	5,888	46.44	10,729	47.54	1,423	45.49	12,152	47.29
F.D.	3,434	48.95	510	45.95	3,944	48.54	4,118	49.79	596	48.18	4,714	49.58
F.D.I.	6.63		7.22		6.70		3.84		4.19		3.88	
A:												
L.B.	4,093	36.71	588	38.43	4,681	36.92	8,158	36.15	1,210	38.68	9,368	36.45
F.D.	2,558	36.46	419	37.75	2,977	36.64	2,940	35.55	425	34.36	3,365	35.39
F.D.I.	6.25		7.13		6.36		3.60		3.51		3.59	
B:												
L.B.	1,406	12.61	182	11.90	1,588	12.52	2,762	12.24	363	11.61	3,125	12.16
F.D.	746	10.63	129	11.62	875	10.77	917	11.09	170	13.74	1,087	11.43
F.D.I.	5.31		7.09		5.51		3.32		4.68		3.48	
AB:												
L.B.	468	4.20	54	3.53	522	4.12	921	4.08	132	4.22	1,053	4.10
F.D.	277	3.95	52	4.68	329	4.05	295	3.57	46	3.72	341	3.59
F.D.I.	5.92		9.63		6.30		3.20		3.48		3.24	
All ABO types:												
L.B.	11,149	.....	1,530	.....	12,679	.....	22,570	.....	3,128	.....	25,698	.....
F.D.	7,015	.....	1,110	.....	8,125	.....	8,270	.....	1,237	.....	9,507	.....
F.D.I.	6.29		7.25		6.41		3.66		3.95		3.70	
	Boundary, 25 Years*											
O:												
L.B.	10,595	46.92	1,411	45.02	12,006	46.69	5,316	47.74	718	47.11	6,034	47.66
F.D.	5,636	49.37	845	46.87	6,481	49.03	1,916	49.52	261	47.98	2,177	49.33
F.D.I.	5.32		5.99		5.40		3.60		3.64		3.61	
A:												
L.B.	8,214	36.37	1,217	38.83	9,431	36.67	4,037	36.25	581	38.12	4,618	36.48
F.D.	4,096	35.88	644	35.72	4,740	35.86	1,402	36.24	200	36.76	1,602	36.30
F.D.I.	4.99		5.29		5.03		3.47		3.44		3.47	
B:												
L.B.	2,814	12.46	385	12.28	3,199	12.44	1,354	12.16	160	10.50	1,514	11.96
F.D.	1,254	10.98	231	12.81	1,485	11.23	409	10.57	68	12.50	477	10.81
F.D.I.	4.46		6.00		4.64		3.02		4.25		3.15	
AB:												
L.B.	960	4.25	121	3.86	1,081	4.20	429	3.85	65	4.27	494	3.90
F.D.	430	3.77	83	4.60	513	3.88	142	3.67	15	2.76	157	3.56
F.D.I.	4.48		6.86		4.75		3.31		2.31		3.18	
All ABO types:												
L.B.	22,583	.....	3,134	.....	25,717	.....	11,136	.....	1,524	.....	12,660	.....
F.D.	11,416	.....	1,803	.....	13,219	.....	3,869	.....	544	.....	4,413	.....
F.D.I.	5.06		5.75		5.14		3.47		3.57		3.49	

* Maternal age group boundary = age separating "older" and "younger" mothers: 30, "older" mothers = those 30 years of age and above, "younger" mothers = those under 30; 25, "older" mothers = those 25 years of age and above, "younger" mothers = those under 25.

APPENDIX A—TABLE A8

ABO AND RH DISTRIBUTION OF WHITE MOTHERS OF ALL AGES BY GESTATIONAL AGE OF FETAL DEATHS (1954–1956)

BLOOD TYPE OF MOTHER	EARLY			MID			LATE		
	Rh+	Rh−	Combined	Rh+	Rh−	Combined	Rh+	Rh−	Combined
O:									
L.B.....	15,912	2,129	18,041	15,912	2,129	18,041	15,912	2,129	18,041
F.D.....	5,012	616	5,628	694	113	807	1,755	358	2,113
F.D.I....	3.15	2.89	3.12	0.44	0.53	0.45	1.10	1.68	1.17
A:									
L.B.....	12,252	1,798	14,050	12,252	1,798	14,050	12,252	1,798	14,050
F.D.....	3,637	492	4,129	512	84	596	1,271	251	1,522
F.D.I....	2.97	2.74	2.99	0.42	0.47	0.42	1.04	1.40	1.08
B:									
L.B.....	4,169	545	4,714	4,169	545	4,714	4,169	545	4,714
F.D.....	1,051	169	1,220	192	27	219	398	104	502
F.D.I....	2.52	3.10	2.59	0.46	0.50	0.46	0.95	1.91	1.06
AB:									
L.B.....	1,389	186	1,575	1,389	186	1,575	1,389	186	1,575
F.D.....	344	48	392	59	6	65	158	43	201
F.D.I....	2.48	2.58	2.49	0.42	0.32	0.41	1.14	2.31	1.28
All ABO types:									
L.B.....	33,722	4,658	38,380	33,722	4,658	38,380	33,722	4,658	38,380
F.D.....	10,044	1,325	11,369	1,457	230	1,687	3,582	756	4,338
F.D.I....	2.98	2.84	2.96	0.43	0.49	0.44	1.06	1.62	1.13

NOTE.—Early fetal deaths: gestational age <20 weeks. Mid fetal deaths: gestational age 20–27 weeks. Late fetal deaths: gestational age 28 weeks or more.

APPENDIX A—TABLE A9

ABO AND RH DISTRIBUTION OF WHITE MOTHERS BY MATERNAL AGE GROUPS FOR EARLY FETAL DEATHS (1954–1956)

BLOOD TYPE OF MOTHER	OLDER MOTHERS						YOUNGER MOTHERS					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Boundary, 30 Years*												
O:												
L.B.	5,182	46.48	706	46.14	5,888	46.44	10,729	47.54	1,423	45.49	12,152	47.29
F.D.	2,296	49.15	269	43.74	2,565	48.52	2,694	50.50	346	48.87	3,040	50.31
F.D.I.	4.43		3.81		4.36		2.51		2.43		2.50	
A:												
L.B.	4,093	36.71	588	38.43	4,681	36.92	8,158	36.15	1,210	38.68	9,368	36.45
F.D.	1,715	36.72	252	40.98	1,967	37.21	1,909	35.78	240	33.90	2,149	35.56
F.D.I.	4.19		4.29		4.20		2.34		1.98		2.29	
B:												
L.B.	1,406	12.61	182	11.90	1,588	12.52	2,762	12.24	363	11.60	3,125	12.16
F.D.	479	10.25	71	11.54	550	10.40	569	10.67	97	13.70	666	11.02
F.D.I.	3.41		3.90		3.46		2.06		2.67		2.13	
AB:												
L.B.	468	4.20	54	3.53	522	4.12	921	4.08	132	4.22	1,053	4.10
F.D.	181	3.87	23	3.74	204	3.86	163	3.06	25	3.53	188	3.11
F.D.I.	3.87		4.26		3.91		1.77		1.89		1.79	
All ABO types:												
L.B.	11,149	.....	1,530	.....	12,679	.....	22,570	.....	3,128	.....	25,698	.....
F.D.	4,671	.....	615	.....	5,286	.....	5,335	.....	708	.....	6,043	.....
F.D.I.	4.19		4.02		4.17		2.36		2.26		2.35	
Boundary, 25 Years*												
O:												
L.B.	10,595	46.92	1,411	45.02	12,006	46.69	5,316	47.74	718	47.11	6,034	47.66
F.D.	3,764	49.70	460	45.59	4,224	49.21	1,226	50.41	155	49.36	1,381	50.29
F.D.I.	3.55		3.26		3.52		2.31		2.16		2.29	
A:												
L.B.	8,214	36.37	1,217	38.83	9,431	36.67	4,037	36.25	581	38.12	4,618	36.48
F.D.	2,735	36.11	375	37.17	3,110	36.23	889	36.55	117	37.26	1,006	36.64
F.D.I.	3.33		3.08		3.30		2.20		2.01		2.18	
B:												
L.B.	2,814	12.46	385	12.28	3,199	12.44	1,354	12.16	160	10.50	1,514	11.96
F.D.	809	10.68	133	13.18	942	10.98	239	9.83	35	11.15	274	9.98
F.D.I.	2.87		3.45		2.94		1.77		2.19		1.81	
AB:												
L.B.	960	4.25	121	3.86	1,081	4.20	429	3.85	65	4.27	494	3.90
F.D.	266	3.51	41	4.06	307	3.58	78	3.21	7	2.23	85	3.10
F.D.I.	2.77		3.39		2.84		1.82		1.08		1.72	
All ABO types:												
L.B.	22,583	.....	3,134	.....	25,717	.....	11,136	.....	1,524	.....	12,660	.....
F.D.	7,574	.....	1,009	.....	8,583	.....	2,432	.....	314	.....	2,746	.....
F.D.I.	3.35		3.22		3.34		2.18		2.06		2.17	

* Maternal age group boundary = age separating "older" and "younger" mothers: 30, "older" mothers = those 30 years of age and above, "younger" mothers = those under 30; 25, "older" mothers = those 25 years of age and above, "younger" mothers = those under 25.

APPENDIX A—TABLE A10

ABO AND RH DISTRIBUTION OF WHITE MOTHERS BY MATERNAL AGE GROUPS FOR MID-GESTATIONAL DEATHS (1954–1956)

Blood Type of Mother	Older Mothers						Younger Mothers					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
	Boundary, 30 Years*											
O:												
L.B.	5,182	46.48	706	46.14	5,888	46.44	10,729	47.54	1,423	45.49	12,152	47.29
F.D.	293	47.49	61	53.04	354	48.36	397	47.60	52	45.61	449	47.36
F.D.I.	0.57		0.86		0.60		0.37		0.37		0.37	
A:												
L.B.	4,093	36.71	588	38.43	4,681	36.92	8,158	36.15	1,210	38.68	9,368	36.45
F.D.	224	36.30	41	35.65	265	36.20	287	34.41	42	36.84	329	34.70
F.D.I.	0.55		0.70		0.57		0.35		0.35		0.35	
B:												
L.B.	1,406	12.61	182	11.90	1,588	12.52	2,762	12.24	363	11.60	3,125	12.16
F.D.	77	12.48	10	8.70	87	11.89	114	13.67	17	14.91	131	13.82
F.D.I.	0.55		0.55		0.55		0.41		0.47		0.42	
AB:												
L.B.	468	4.20	54	3.53	522	4.12	921	4.08	132	4.22	1,053	4.10
F.D.	23	3.73	3	2.61	26	3.55	36	4.32	3	2.63	39	4.11
F.D.I.	0.49		0.56		0.50		0.39		0.23		0.37	
All ABO types:												
L.B.	11,149	.....	1,530	.....	12,679	.....	22,570	.....	3,128	.....	25,698	.....
F.D.	617	.....	115	.....	732	.....	834	.....	114	.....	948	.....
F.D.I.	0.55		0.75		0.58		0.37		0.36		0.37	
	Boundary, 25 Years*											
O:												
L.B.	10,595	46.92	1,411	45.02	12,006	46.69	5,316	47.74	718	47.11	6,034	47.66
F.D.	497	47.56	90	52.02	587	48.19	193	47.54	23	41.07	216	46.75
F.D.I.	0.47		0.64		0.49		0.36		0.32		0.36	
A:												
L.B.	8,214	36.37	1,217	38.83	9,431	36.67	4,037	36.25	581	38.12	4,618	36.48
F.D.	372	35.60	60	34.68	432	35.47	139	34.24	23	41.07	162	35.06
F.D.I.	0.45		0.49		0.46		0.34		0.40		0.35	
B:												
L.B.	2,814	12.46	385	12.28	3,199	12.44	1,354	12.16	160	10.50	1,514	11.96
F.D.	133	12.73	17	9.83	150	12.32	58	14.29	10	17.86	68	14.72
F.D.I.	0.47		0.44		0.47		0.43		0.63		0.45	
AB:												
L.B.	960	4.25	121	3.86	1,081	4.20	429	3.85	65	4.27	494	3.90
F.D.	43	4.11	6	3.47	49	4.02	16	3.94	0	0.00	16	3.46
F.D.I.	0.45		0.50		0.45		0.37		0.00		0.32	
All ABO types:												
L.B.	22,583	.....	3,134	.....	25,717	.....	11,136	.....	1,524	.....	12,660	.....
F.D.	1,045	.....	173	.....	1,218	.....	406	.....	56	.....	462	.....
F.D.I.	0.46		0.55		0.47		0.36		0.37		0.36	

* Maternal age group boundary = age separating "older" and "younger" mothers: 30, "older" mothers = those 30 years of age and above, "younger" mothers = those under 30; 25, "older" mothers = those 25 years of age and above, "younger" mothers = those under 25.

APPENDIX A—TABLE A11

ABO AND RH DISTRIBUTION OF WHITE MOTHERS BY MATERNAL AGE GROUPS FOR LATE FETAL DEATHS (1954–1956)

BLOOD TYPE OF MOTHER	OLDER MOTHERS						YOUNGER MOTHERS					
	Rh+		Rh−		Combined		Rh+		Rh−		Combined	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
	Boundary, 30 Years*											
O:												
L.B.	5,182	46.48	706	46.14	5,888	46.44	10,729	47.54	1,423	45.49	12,152	47.29
F.D.	790	48.68	172	47.12	962	48.39	963	49.28	185	47.44	1,148	48.98
F.D.I.	1.52		2.44		1.63		0.90		1.30		0.94	
A:												
L.B.	4,093	36.71	588	38.43	4,681	36.92	8,158	36.15	1,210	38.68	9,368	36.45
F.D.	582	35.86	119	32.60	701	35.26	688	35.21	132	33.85	820	34.98
F.D.I.	1.42		2.02		1.50		0.84		1.09		0.88	
B:												
L.B.	1,406	12.61	182	11.89	1,588	12.52	2,762	12.24	363	11.60	3,125	12.16
F.D.	181	11.15	48	13.15	229	11.52	215	11.00	56	14.36	271	11.56
F.D.I.	1.29		2.64		1.44		0.78		1.54		0.87	
AB:												
L.B.	468	4.20	54	3.53	522	4.12	921	4.08	132	4.22	1,053	4.10
F.D.	70	4.31	26	7.12	96	4.83	88	4.50	17	4.36	105	4.48
F.D.I.	1.50		4.81		1.84		0.96		1.29		1.00	
All ABO types:												
L.B.	11,149	.....	1,530	.....	12,679	.....	22,570	.....	3,128	.....	25,698	.....
F.D.	1,623	.....	365	.....	1,988	.....	1,954	.....	390	.....	2,344	.....
F.D.I.	1.46		2.39		1.57		0.87		1.25		0.91	
	Boundary, 25 Years*											
O:												
L.B.	10,595	46.92	1,411	45.02	12,006	46.69	5,316	47.74	718	47.11	6,034	47.66
F.D.	1,289	49.12	279	47.21	1,568	48.77	464	48.69	78	47.56	542	48.52
F.D.I.	1.22		1.98		1.31		0.87		1.09		0.90	
A:												
L.B.	8,214	36.37	1,217	38.83	9,431	36.67	4,037	36.25	581	38.12	4,618	36.48
F.D.	928	35.37	196	33.16	1,124	34.96	342	35.89	55	33.54	397	35.54
F.D.I.	1.13		1.61		1.19		0.85		0.95		0.86	
B:												
L.B.	2,814	12.46	385	12.28	3,199	12.44	1,354	12.16	160	10.50	1,514	11.96
F.D.	293	11.17	81	13.71	374	11.63	103	10.81	23	14.02	126	11.28
F.D.I.	1.04		2.10		1.17		0.76		1.44		0.83	
AB:												
L.B.	960	4.25	121	3.86	1,081	4.20	429	3.85	65	4.27	494	3.90
F.D.	114	4.34	35	5.92	149	4.63	44	4.62	8	4.88	52	4.66
F.D.I.	1.19		2.89		1.38		1.03		1.23		1.05	
All ABO types:												
L.B.	22,583	.....	3,134	.....	25,717	.....	11,136	.....	1,524	.....	12,660	.....
F.D.	2,624	.....	591	.....	3,215	.....	953	.....	164	.....	1,117	.....
F.D.I.	1.16		1.89		1.25		0.86		1.08		0.88	

* Maternal age group boundary = age separating "older" and "younger" mothers: 30, "older" mothers = those 30 years of age and above, "younger" mothers = those under 30; 25, "older" mothers = those 25 years of age and above, "younger" mothers = those under 25.

APPENDIX B—TABLE B1

MATERNAL ABO BLOOD TYPE AND RISK OF FETAL DEATH

	WHITES							NEGROES						
	Blood Type of Mother	Fetal Deaths	Live Births (10%)	% Fetal Deaths*	Comparison Ratios of F.D.I.'s	Relative Frequency†	χ^2 (1 df)	Blood Type of Mother	Fetal Deaths	Live Births (10%)	% Fetal Deaths*	Comparison Ratios of F.D.I.'s	Relative Frequency†	χ^2 (1 df)
1954–1959	O.....	17,575	36,230	4.85	O/non-O..	1.10	59.40	O.....	6,226	7,867	7.91	O/non-O..	0.96	2.50
	B.....	3,821	9,220	4.14	O/AB.....	1.12	10.87	B.....	2,435	3,109	7.83	O/AB.....	0.86	6.07
	A.....	12,525	27,955	4.48	B/AB.....	0.95	1.49	A.....	3,295	3,932	8.38	B/AB.....	0.85	6.21
	AB.....	1,357	3,127	4.34	A/AB.....	1.03	0.87	AB.....	536	581	9.23	A/AB.....	0.91	2.23
	Combined.	35,278	76,532	4.61				Combined.	12,492	15,489	8.07			
1954–1956	O.....	8,789	18,095	4.86	O/non-O..	1.09	22.31	O.....	2,850	3,627	7.86	O/non-O..	0.98	0.50
	B.....	1,989	4,723	4.21	O/AB.....	1.12	6.06	B.....	1,119	1,408	7.95	O/AB.....	1.03	0.07
	A.....	6,421	14,089	4.55	B/AB.....	0.97	0.23	A.....	1,460	1,778	8.21	B/AB.....	1.04	0.14
	AB.....	683	1,581	4.32	A/AB.....	1.05	1.23	AB.....	219	286	7.66	A/AB.....	1.07	0.52
	Combined.	17,882	38,488	4.65				Combined.	5,648	7,099	7.96			
1957–1959	O.....	8,786	18,135	4.84	O/non-O..	1.12	38.46	O.....	3,376	4,240	7.96	O/non-O..	0.95	2.20
	B.....	1,832	4,497	4.07	O/AB.....	1.11	4.84	B.....	1,316	1,701	7.74	O/AB.....	0.74	12.70
	A.....	6,104	13,866	4.40	B/AB.....	0.93	1.59	A.....	1,835	2,154	8.52	B/AB.....	0.72	13.68
	AB.....	674	1,546	4.36	A/AB.....	1.01	0.04	AB.....	317	295	10.75	A/AB.....	0.79	7.14
	Combined.	17,396	38,044	4.57				Combined.	6,844	8,390	8.16			

* In Newcombe's terminology "% Fetal Deaths" corresponds to "fetal death index'" in this report.

† "Relative Frequency" corresponds to "Comparison Ratio" as used in this report.

APPENDIX B—TABLE B2

MATERNAL RH BLOOD TYPE AND RISK OF FETAL DEATH (1954-1956)

Blood Type of Mother	Fetal Deaths	Live Births (10%)	% Fetal Deaths	Comparison	Relative Frequency*	χ^2 (1 df)
Whites:						
Rh-negative..	2,354	4,658	5.05	Rh-neg./Rh-pos.	1.11	15.15
Rh-positive...	15,336	33,722	4.55	.....	.....	.....
Negroes:						
Rh-negative..	346	502	6.89	Rh-neg./Rh-pos.	0.86	4.15
Rh-positive...	5,239	6,578	7.96	.....	.....	.....

* "Relative Frequency" corresponds to "Comparison Ratio" as used in this report.

APPENDIX B—TABLE B3

RISK OF FETAL DEATH BY COMBINED ABO AND RH TYPE OF MOTHER

Blood Type of Mother	Fetal Deaths	Live Births (10%)	% Fetal Deaths	Comparison	Relative Frequency*	χ^2 (1 df)
Whites:						
AB Rh-negative....	98	186	5.27	AB, Rh-neg./Rh-pos.	1.28	3.36
O Rh-positive.....	7,581	15,912	4.76	B, Rh-neg./Rh-pos.	1.37	16.82
B Rh-negative....	300	545	5.50	A, Rh-neg./Rh-pos.	1.05	1.11
O Rh-negative....	1,108	2,129	5.20	O, Rh-neg./Rh-pos.	1.09	4.98
A Rh-negative....	848	1,798	4.72	.....	.....	.....
B Rh-positive.....	1,670	4,169	4.01	.....	.....	.....
A Rh-positive.....	5,513	12,252	4.50	.....	.....	.....
AB Rh-positive.....	572	1,389	4.12	.....	.....	.....
Negroes:						
AB Rh-negative....	13	23	5.65	AB, Rh-neg./Rh-pos.	0.73	0.77
O Rh-positive.....	2,667	3,369	7.92	B, Rh-neg./Rh-pos.	0.88	0.62
B Rh-negative....	73	104	7.02	A, Rh-neg./Rh-pos.	1.07	0.24
O Rh-negative....	155	254	6.10	O, Rh-neg./Rh-pos.	0.77	6.12
A Rh-negative....	105	121	8.68	.....	.....	.....
B Rh-positive.....	1,032	1,298	7.95	.....	.....	.....
A Rh-positive.....	1,337	1,649	8.11	.....	.....	.....
AB Rh-positive.....	203	262	7.75	.....	.....	.....

* "Relative Frequency" corresponds to "Comparison Ratio" as used in this report.

APPENDIX B—TABLE B4

RISK OF FETAL DEATH TO OLDER MOTHERS OF DIFFERENT BLOOD TYPES

Blood Type of Mother	Fetal Deaths	Live Births (10%)	% Fetal Deaths	Relative Frequency*	χ^2 (1 df)
White mothers age 25 and over:					
AB Rh-negative	83	121	6.86	1.53	7.60
AB Rh-positive	430	960	4.48		
B Rh-negative	231	385	6.00	1.35	10.95
B Rh-positive	1,254	2,814	4.46		
O Rh-negative	845	1,411	5.99	1.13	6.49
O Rh-positive	5,636	10,595	5.32		
A Rh-negative	644	1,217	5.29	1.06	1.29
A Rh-positive	4,096	8,214	4.99		
Negro mothers age 25 and over:					
AB Rh-negative	12	11	10.91	1.42	0.64
AB Rh-positive	124	161	7.70		
B Rh-negative	52	57	9.12	0.92	0.17
B Rh-positive	683	690	9.90		
O Rh-negative	111	131	8.47	0.89	0.84
O Rh-positive	1,769	1,848	9.57		
A Rh-negative	64	55	11.64	1.12	0.38
A Rh-positive	900	869	10.36		

* "Relative Frequency" corresponds to "Comparison Ratio" as used in this report.

APPENDIX B—TABLE B5

EFFECT OF MATERNAL AGE ON RELATIVE FREQUENCY OF FETAL DEATHS TO AB RH-NEGATIVE AND AB RH-POSITIVE MOTHERS

Age Group of Mother	AB Rh-negative Mothers		AB Rh-positive Mothers		Relative Frequency*	χ^2 (1 df)
	Fetal Deaths	Live Births (10%)	Fetal Deaths	Live Births (10%)		
Whites:						
0–19	2	9	17	69	0.90	0.02
20–24	13	56	125	360	0.67	1.54
25–29	31	67	153	492	1.49	2.83
30–39	46	52	242	445	1.63	5.00
40–49	6	2	35	23	1.97	0.62
Weighted mean (all ages)					1.32	4.01
Weighted mean (ages 25 and up)					1.57	8.31
Negroes:						
0–19	1	1	17	25	1.47	7.09
20–24	0	11	62	76	0.00	
25–29	6	4	48	82	2.56	1.97
30–39	4	7	70	78	0.64	0.49
40–49	2	0	6	1		
Weighted mean (all ages)					1.04	0.01
Weighted mean (ages 25 and up)					1.25	0.22

NOTE.—Age groups 30–34 and 35–39 are combined here, whereas Newcombe presented these groups separately.
* "Relative Frequency" corresponds to "Comparison Ratio" as used in this report.

APPENDIX B—TABLE B6

EFFECT OF ABSENCE OF ABO BLOOD FACTORS IN RH-NEGATIVE AND RH-POSITIVE MOTHERS AGE 25 AND OVER ON THE RISK OF FETAL DEATH

ABO Factor Missing from Mother	Risk of Fetal Death (per 100 Live Births)	Difference as Compared with "Neither Missing"	% Change in Risk
	Whites		
Rh-negative mothers:			
Neither missing	6.86		
A missing	5.99	−0.87	12.68% decrease
B missing	5.67	−1.19	17.35% decrease
Both missing	5.99	−0.87	12.68% decrease
Rh-positive mothers:			
Neither missing	4.48		
A missing	5.14	+0.66	14.73% increase
B missing	5.17	+0.69	15.40% increase
Both missing	5.32	+0.84	18.75% increase
	Negroes		
Rh-negative mothers:			
Neither missing	10.91		
A missing	8.67	−2.24	20.53% decrease
B missing	9.41	−1.50	13.75% decrease
Both missing	8.47	−2.44	22.36% decrease
Rh-positive mothers:			
Neither missing	7.70		
A missing	9.66	+1.96	24.45% increase
B missing	9.82	+2.12	27.53% increase
Both missing	9.57	+1.87	24.29% increase

APPENDIX B—TABLE B7

EXPECTED PROPORTIONS OF INCOMPATIBLE FETUSES TO WHITE AND NEGRO MOTHERS OF DIFFERENT PHENOTYPES

Kind of Incompatibility	% of Fetuses Incompatible, by Maternal ABO and Rh Phenotype							
	O Rh-neg.	O Rh-pos.	A Rh-neg.	A Rh-pos.	B Rh-neg.	B Rh-pos.	AB Rh-neg.	AB Rh-pos.
White mothers:*								
ABO only (single)	12.6	32.5	3.6	9.4	9.0	23.1	00.0	00.0
Rh only (single)	41.3	00.0	55.4	00.0	47.1	00.0	61.2	00.0
ABO and Rh (double)	19.9	00.0	5.8	00.0	14.1	00.0	00.0	00.0
Negro mothers:†								
ABO only (single)	10.1	33.5	4.4	14.8	4.4	19.8	00.0	00.0
Rh only (single)	46.0	00.0	59.6	00.0	56.1	00.0	70.0	00.0
ABO and Rh (double)	23.5	00.0	10.4	00.0	13.9	00.0	00.0	00.0

NOTE.—Expected ABO allele frequencies used here are for New York City whites and Negroes from Wiener (1943), whereas frequencies used by Newcombe were for combined New York and North Carolina whites and for North Carolina Negroes, respectively. Expected Rh allele frequencies used here are for New York City whites and Negroes from Wiener and Wexler (1958), whereas figures used by Newcombe were from Sinnott, Dunn, and Dobzhansky (1958).

* Based on allele frequencies: O = .675, A = .231, B = .094 (from Tiber as quoted by Wiener, 1943); Rh-negative = .388, Rh-positive = .612 (from Wiener and Wexler, 1958).

† Based on allele frequencies: O = .665, A = .198, B = .148 (from Landsteiner and Levine as quoted by Wiener, 1943); Rh-negative = .3, Rh-positive = .7 (from Wiener and Wexler, 1958).

APPENDIX B—TABLE B8

PROPORTIONS OF RH BLOOD TYPES AMONG MOTHERS OF DIFFERENT ABO CONSTITUTIONS AND OF DIFFERENT AGE GROUPS

ABO Blood Type of Mother	Rh-positive Mothers of Live-born	Rh-negative Mothers of Live-born	Ratio Pos./Neg. (for Mothers of Live-born)	Ratio Pos./Neg. (for Mothers of Dead Fetuses)
	Whites			
All ages of mother:				
AB	1,389	186	7.47	5.84
O	15,912	2,129	7.47	6.84
B	4,169	545	7.65	5.57
A	12,252	1,798	6.81	6.50
Mothers 25 and over:				
AB	960	121	7.93	5.18
O	10,595	1,411	7.51	6.67
B	2,814	385	7.31	5.43
A	8,214	1,217	6.75	6.36
	Negroes			
All ages of mother:				
AB	262	23	11.39	15.62
O	3,369	254	13.26	17.21
B	1,298	104	12.48	14.14
A	1,649	121	13.63	12.73
Mothers 25 and over:				
AB	161	11	14.64	10.33
O	1,848	131	14.11	15.94
B	690	57	12.11	13.13
A	869	55	15.80	14.06

APPENDIX B—TABLE B9

PROPORTION OF RH-POSITIVE MOTHERS OF LIVE-BORN INFANTS AMONG THOSE WHO ARE AB AS COMPARED WITH A, BY AGE GROUP OF MOTHER

AGE GROUP OF MOTHER	AB MOTHERS OF LIVE-BORN		A MOTHERS OF LIVE-BORN		RELATIVE FREQUENCY*	χ^2 (1 df)
	Rh-positive	Rh-negative	Rh-positive	Rh-negative		
Whites:						
0–19	69	9	570	103	1.39	0.78
20–24	360	56	3,467	478	0.88	0.63
25–29	492	67	4,121	629	1.12	0.69
30–39	445	52	3,825	547	1.22	1.73
40–49	23	2	268	41	1.76	0.56
Weighted mean (all ages)					1.09	1.10
Weighted mean (ages 25 and up)					1.17	2.51
Negroes:						
0–19	25	1	240	12	1.25	0.04
20–24	76	11	539	54	0.69	1.09
25–29	82	4	455	25	1.13	0.05
30–39	78	7	397	28	0.79	0.30
40–49	1	0	17	2		
Weighted mean (all ages)					0.81	0.75
Weighted mean (ages 25 and up)					0.90	0.09

NOTE.—Age groups 30–34 and 35–39 are combined here, whereas Newcombe presented these groups separately.
* "Relative Frequency" corresponds to "Comparison Ratio" as used in this report.

APPENDIX B—TABLE B10

EFFECT OF MATERNAL AGE ON THE PROPORTIONS OF RH BLOOD TYPES AMONG ALL MOTHERS OF LIVE-BORN INFANTS

AGE GROUP OF MOTHER	ALL MOTHERS OF LIVE-BORN		RATIO POSITIVE/ NEGATIVE	RELATIVE INCIDENCE	χ^2 (1 df)
	Rh-positive	Rh-negative			
Whites:					
0–19	1,738	245	7.09		
20–24	9,398	1,279	7.35		
25–29	11,434	1,604	7.13		
30–39	10,424	1,427	7.30		
40–49	725	103	7.04		
Comparison 25–39	21,858	3,031	7.21	0.99	0.11
Not in this range	11,861	1,627	7.29		
Negroes:					
0–19	964	51	18.55		
20–24	2,063	197	10.47		
25–29	1,818	104	17.48		
30–39	1,667	144	11.58		
40–49	83	6	13.83		
Comparison 25–39	3,485	248	14.05	1.15	2.40
Not in this range	3,092	254	12.17		

NOTE.—Age groups 30–34 and 35–39 are combined here as 30–39. Comparison is for 25–39 with those not in this range, whereas Newcombe used the 25–34 group in comparison with those not in that range.