Fetal Deaths Related to Maternal Injury

Harold B. Weiss, PhD, MPH, MS
Thomas J. Songer, PhD, MSc
Anthony Fabio, PhD

Context Maternal and fetal trauma is an important cause of adverse fetal outcomes. However, systematic exclusion from US injury surveillance programs of even the most severe outcome, fetal/neonatal death, has led to a lack of understanding about frequency, causes, and prevention.

Objective To determine the rate of traumatic fetal deaths reported in state fetal death registries and the types of trauma and physiologic diagnoses associated with these deaths.

Design and Setting Retrospective descriptive study of fetal death certificates from 1995 through 1997 obtained from 16 states, which accounted for 55% of US live births and approximately 15000 fetal death registrations per year.

Main Outcome Measure Rate of fetal injury deaths, based on fetal death certificates coded with an underlying cause of death due to maternal injury at 20 weeks' gestation or later, by cause.

Results During the 3-year study period, 240 traumatic fetal injury deaths were identified (3.7 fetal deaths per 100000 live births). Motor vehicle crashes were the leading trauma mechanism (82% of cases; 2.3 fetal deaths per 100000 live births), followed by firearm injuries (6% of cases) and falls (3% of cases). In 3 states, reported crash-related fetal deaths exceeded that of crash-related infant deaths. Placental injury was mentioned in 100 cases (42%) and maternal death was noted in 27 cases (11%). A peak rate of 9.3 fetal deaths per 100000 live births was observed among 15- to 19-year-old women.

Conclusions Motor vehicle crashes are the leading cause of fetal deaths related to maternal trauma. Improved tracking of traumatic fetal injury deaths is important to stimulate and guide research and efforts to reduce the risks to women and fetuses from injury during pregnancy.

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TRAUMA DURING PREGNANCY HAS been recognized as an important cause of adverse fetal and maternal outcomes.[1] While early reports described incidents resulting from falls, blows, and assaults,[2] later reports increasingly involved automobile crashes.[3,4] By the mid-1960s, the problem of pregnancy and motor vehicle crashes was recognized by trauma and obstetric specialists.[5-7] Over the next decade, many hospital-based case series of fetal outcome following maternal trauma were published.[8-17] However, even for the most severe outcomes resulting in fetal or neonatal death, the lack of inclusion of such cases in vital statistics reports and exclusion from injury surveillance systems have led to a lack of population-based statistics. These data are needed to understand the relative public health burden and the proportional contributions of different injury mechanisms. Such understanding is needed to put these incidents in context with other injury-related deaths and to target prevention efforts.

In their report of fetal motor vehicle–related deaths from 9 county series of coroner cases, Agran et al[18] were the first to suggest that fetal crash-related deaths might represent an important but unreported proportion of motor vehicle–related deaths. Lane[19] reported a coroner series of motor vehicle–related third-trimester fetal deaths in Ontario from 1982 to 1986, but did not describe other causes of traumatic fetal deaths.

In addition, few reports on fetal death and stillbirth separate trauma as a cause of death and none report contributions by injury types.[20-23] This occurs because international coding conventions subsume these cases to a nonspecific code for "death due to maternal injury," often included in broader categories. Further, because the *International Classification of Diseases* (*ICD*) code for death due to maternal injury (760.5) is neither an external cause (E-code) nor in the range included in most injury case definitions, such cases have gone unreported in state and national injury surveillance reports. In crash data systems, fetal deaths are excluded from the case definition of a crash victim. Without case ascertainment and population-based surveillance, the magnitude and trends of the fetal deaths from trauma, as well as who is at risk, and what circumstances carry the highest risk will remain unknown. This makes it impossible to prioritize, develop, and evaluate effective prevention strategies.

This study sought to answer the following questions: (1) What is the rate

Author Affiliations: Center for Injury Research and Control, Department of Neurosurgery (Drs Weiss and Fabio) and Graduate School of Public Health, University of Pittsburgh (Dr Songer), Pittsburgh, Pa.
Corresponding Author and Reprints: Harold B. Weiss, PhD, MPH, MS, Center for Injury Research and Control, University of Pittsburgh, 200 Lothrop St, Suite B400, Pittsburgh, PA 15213 (e-mail: hweiss@injurycontrol.com).

of traumatic fetal injury deaths reported in state fetal death registries? (2) What types of trauma are responsible for these deaths? and (3) What are the physiologic diagnoses associated with these deaths?

METHODS

Data Sources and Retrieval

Most state health departments maintain fetal death registries.[24,25] Similar to standard death certificates, fetal death certificates include sections for identifiers, demographics, and cause of death narratives but also document pregnancy risk factors. In most states, only fetal deaths of 20 weeks' gestation or more are reported.[24] E-codes that classify mechanisms of injury death (car crashes, falls, firearms, etc) are rarely used. Therefore, to obtain details on injury mechanisms, it was necessary to examine certificate narratives.

A feasibility study was conducted to ascertain the usefulness of the maternal injury *ICD* code.[26] All 4925 fetal death certificates (all causes) for 1995 and 1996 in 1 large state were hand reviewed. Each manually identified traumatic fetal death was compared with the state's computerized listing of 760.5 coded cases. All 17 computer file cases were identified by the manual review and if maternal injury was listed as the cause of death on the certificate it was coded 760.5, suggesting that the 760.5 code would comprise an efficient screen for potential cases. The pilot study also showed that mechanism of injury was usually available in the fetal death certificate narrative.

Next, all US health departments were queried about the accessibility and usability of their fetal death registry. Incomplete responses were received from 8 states. Four states would not allow external research using their fetal death certificates. Twenty-two others had policies or practices that prevented access to or hindered use of the data (eg, lack of computerization or coding). Formal data requests were then sent to the 16 remaining states, which represent 55% of the US live births and approximately 15 000 fetal death registrations per year during the study period from 1995 through 1997. States were asked to screen their computerized registries and provide death certificates for all cases with an underlying cause code of 760.5.

Data Abstraction and Coding

A certified nosologist assigned E-codes by examining fetal or maternal conditions causing fetal death, other significant conditions contributing to fetal death, and other certificate narrative. After data entry and export to SPSS Windows version 8.0 (SPSS Inc, Chicago, Ill), range and frequency checks were run and the data manually reviewed for outliers and miscodes. Potential errors were examined and compared with the original death certificate. To reduce the risk of introducing bias from the 23 records that were missing fetal age, we used available data on fetal weight and age from existing cases and linear regression to estimate gestational age similar to methods reported by Gaudino et al.[27]

Case Definition

Any fetal death at 20 weeks' gestation or later effected by an in utero traumatic externally caused injury to the fetus or the mother, excluding birth-related trauma and therapeutic abortion, in which the fetus died before birth, was considered a case of traumatic fetal death.

Three certificates were coded 760.5 and marked as pending but had no other evidence of maternal injury. They were included on the assumption that they were cases of maternal injury but lacked official findings as to cause. For 3 pairs of twins, each fetus was counted as a separate case because live birth denominators counted twin births as 2 births. To minimize the number of cases not meeting the case definition, death certificates were excluded if they indicated: (1) a history of nontrauma-related maternal surgery, (2) iatrogenic causes (medical or surgical complications), (3) maternal or fetal injuries occurring more than 30 days prior to the death, (4) exposure to cigarettes, alcohol, or other drugs without evidence of trauma, (5) umbilical cord accidents and fetal asphyxia, (6) amniocentesis, (7) traumatic ruptures of the amniotic sac with no external cause listed, and (8) cases in which death occurred before 20 weeks' gestation. There were 32 exclusions among 272 obtained fetal death certificates, leaving 240 cases for analysis. Placental injury was defined as mention of any of the following placental-related conditions or their common variants: separation, abruption, infarct, rupture, laceration, insufficiency, disturbed uteroplacenta blood flow, or hemorrhage.

Analysis

Fetal injury death rates were calculated as the number of fetal deaths per 100 000 live births in the midpoint year of 1996[28] and the number of traumatic fetal deaths per 1000 reported fetal deaths in 1995 (most recent year available).[29] Traumatic fetal deaths were further classified by subgroups, including state, mechanism of injury, gestational age, and mother's age and race. Overall and mechanism-specific fetal traumatic injury deaths were compared with infant traumatic injury deaths. Point estimates and 95% confidence intervals (CIs) of the rate ratio (RR) comparing fetal deaths with infant deaths were computed per standard methods.[30]

RESULTS

During the 3-year study period, 240 traumatic fetal deaths were identified. There were 3.7 traumatic fetal deaths per 100 000 live births per year (95% CI, 3.2-4.1) with a range by state from 0 to 6.5 (TABLE 1). Fetal traumatic injury–related death was 5.4 per 1000 fetal deaths, with a range by state of 0 to 10. The mean gestational age of affected fetuses was 29.4 (SD, 5.7) weeks. Gestational ages in 4-week groupings were distributed as follows excluding unknowns: 20% at 20 to 23 weeks, 20% at 24 to 27 weeks, 20% at 28 to 31 weeks, 25% at 32 to 35 weeks, and 16% at 36 weeks or greater. A total of 51% of the fetuses were female.

The mean maternal age was 23.8 years (range, 15-42 years). The 15- to 19-year-old age group contained the most cases and the highest rate of fetal injury deaths with the peak rate occurring among 17- to 19-year-olds. A strong inverse relationship was observed by maternal age. The number (9.3) of traumatic fetal injury deaths per 100 000 live births was highest among 15- to 19-year-olds (95% CI, 5.7-12.9) decreasing to 1.7 (95% CI, 0.2-3.3) among women older than 34 years (FIGURE 1). The rates by maternal race were 4.4 deaths per 100 000 live births (95% CI, 3.2-5.5) for blacks and 3.2 deaths per 100 000 live births for whites (95% CI, 2.6-3.6) but the difference was not statistically significant. Rates by ethnicity were 3.9 deaths per 100 000 births for non-Hispanic and 2.8 deaths per 100 000 for Hispanic and ethnicity not stated.

Among traumatic fetal injury death cases with known mechanisms 150 (82%) involved motor vehicle–related crashes, 11 (6%) involved firearm injuries, and 6 (3%) were fall-related. Details on the motor vehicle–related cases are shown by state in TABLE 2. Six cases were coded as intentional injuries and 1 as self-inflicted. Fifty-six (23%) cases could not be coded to an injury mechanism or intent and few E-codes could be assigned to the highest level of detail. For example, while motor vehicle–related codes predominated, there was not enough information on the certificates to differentiate between the mother driving or being a passenger.

Placental injury was reported in 100 cases (42%), both in the narrative and check-box portion of the certificates. Frequently, the check-box was not used even though there was strong indication of placental abruption on the certificate. Younger maternal age groups appeared to have a slightly higher proportion of placental injury but a χ^2 test showed no overall age effect (FIGURE 2). In logistic regression analyses, gestational age was of borderline significance ($P=.05$) as a risk factor for placental injury, but was not a particularly strong predictor ($R=0.085$). Placental injuries were associated with 47% of the motor vehicle occupant–related cases. Of 9 (4%) cases with uterine rupture, 7 were motor vehicle–related and 4 occurred in older, almost full-term fetuses (≥36 weeks' gestation) and none occurred in the 20 to 27 weeks' gestation fetuses. Among all cases, the delivery method was not stated one fourth of the time. When the delivery method was specified (n=179), the proportion of cesarean deliveries was 46%. For comparison, cesarean deliveries were performed 21% of the time among all live births in 1996.[28]

Of the 240 fetal deaths, 27 (11%) maternal deaths were noted. Approximately 26% of the maternal deaths occurred in black women and 11% in Hispanic women, which comprised 19% and 24% of the live births, respectively, in the surveyed states. Among the 22 maternal deaths in which the injury mechanism was specified, 14 (64%) were due to motor vehicle–related causes and 4 (18%) to gunshot wounds.

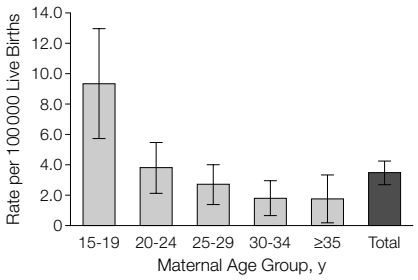
For selected medical factors that were mentioned frequently enough to warrant comparisons, it is possible to compare the occurrence rate of those factors with the population of US live births. Using data from published 1996 natality statistics,[28] RRs and CIs were computed (TABLE 3). The RR was 35.1 (95% CI, 26.4-46.6) for abruptio placenta. The month of initiation of prenatal care was recorded on 157 of the certificates. First-trimester prenatal care began in 71.3% of the cases with known month. For comparison, the National Center for Health Statistics report indicated that 81.8% of all live births began prenatal care in the first trimester in 1996.[28]

Table 1. Fetal Death Certificate Procurement and Annualized Traumatic Fetal Injury–Related Deaths in the United States, 1995-1997*

State	1996 Live Births, No.	1995 Fetal Deaths, No.	Fetal Injury Deaths, No.	Annual Rate per 1000 Fetal Deaths	Annual Rate per 100 000 Live Births
California	539 433	3364	54	5.4	3.3
Texas	330 406	1962	34	5.8	3.4
Illinois	183 180	1270	14	3.7	2.5
Pennsylvania	151 692	1265	26	6.9	5.7
Ohio	148 338	1150	11	3.2	2.5
New Jersey	114 306	720	7	3.2	2.0
Georgia	114 043	1248	15	4.0	4.4
North Carolina	104 470	822	17	6.9	5.4
Massachusetts	80 276	443	6	4.5	2.5
Tennessee	77 945	419	12	9.5	5.1
Washington	73 754	407	8	6.6	3.6
Minnesota	63 700	367	11	10.0	5.8
Kentucky	52 706	383	9	7.8	5.7
South Carolina	51 117	464	10	7.2	6.5
Connecticut	44 469	290	0	0	0
Utah	42 087	234	6	8.5	4.8
Total	**2 171 922**	**14 808**	**240**	5.4	3.7

*Fetal death data in 1995 are from the National Center for Health Statistics.

Figure 1. Fetal Traumatic Injury–Related Mortality by Maternal Age Group, 1995-1997



Fetal traumatic injury–related mortality (with 95% confidence intervals) represents all causes in the sampled states from 1995 through 1997.

COMMENT

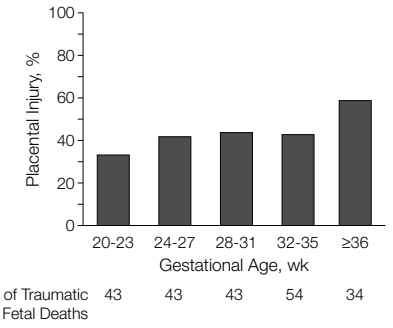
Based on fetal death certificates from 16 states representing 55% of the US live births from 1995 through 1997, a total of 240 traumatic fetal injury deaths were

Table 2. Fetal and Infant Deaths Related to Motor Vehicle–Related (MV) Trauma by State*

	No. of Fetal MV Deaths Reported (1995-1997)	Fetal MV Death Rate per 1000 Fetal Deaths/Year (Annualized)†	Fetal MV Death Rate per 100 000 Live Births (Annualized)‡	No. of Infant MV Deaths Reported (1993-1995)§	Infant MV Death Rate per 100 000 Live Births (Annualized)	Ratio of Fetal vs Infant MV Death Rate per 100 000 Live Births
California	17	1.7	1.1	70	4.3	0.2
Texas	26	4.4	2.6	58	5.9	0.4
Illinois	9	2.4	1.6	18	3.3	0.5
Pennsylvania	20	5.3	4.5	13	2.9	1.5
Ohio	10	2.9	2.2	12	2.6	0.8
New Jersey	4	NA	NA	29	8.5	NA
Georgia	10	2.7	2.9	29	8.5	0.3
North Carolina	10	4.1	3.2	28	9.0	0.4
Massachusetts	4	NA	NA	2	NA	NA
Tennessee	10	8.0	4.5	20	9.1	0.5
Washington	3	NA	NA	5	2.1	NA
Minnesota	6	5.4	3.1	6	3.1	1.0
Kentucky	9	7.8	5.7	4	NA	NA
South Carolina	7	5.0	4.6	18	11.8	0.4
Connecticut	0	NA	NA	1	NA	NA
Utah	5	7.1	4.0	8	6.3	0.6
Total	**150**	3.4	2.3	**321**	4.9	0.5

*NA indicates not applicable due to rates shown only for cells with 5 or more cases.
†Denominator data from the National Center for Health Statistics.[29]
‡Denominator data from 1996 (mid-year) US live births.[28]
§Centers for Disease Control and Prevention. Ten leading causes of death by age group, 1993-1995.

Figure 2. Fetal Traumatic Injury Deaths by Gestational Age and Placental Injury



Proportion represents percentages relative to gestational age group in selected US states from 1995 through 1997.

identified (3.7 deaths per 100 000 live births). Extrapolating these data to the United States would result in approximately 143 fetal deaths per year. An inverse relationship was observed between fetal mortality and maternal age, suggesting that the ages at which women are at highest risk for motor vehicle injury and assault overlap greatly with the ages of high birth rates.

Motor vehicle crashes accounted for 82% of the cases with specified mechanisms; the frequency approached almost half the reported number of infant deaths due to motor vehicle crashes in these states. In 3 states the reported frequency of fetal deaths related to motor vehicles was higher than similarly caused infant deaths. Extrapolating motor vehicle transport–related fetal deaths in this study to the United States suggests that at least 90 motor vehicle–related fetal cases would occur annually. For comparison, an average of 179 cases per year are reported for infant motor vehicle–related deaths.[31]

The motor vehicle–related fetal death estimate is conservative because the cases used for extrapolation do not include (1) estimates of the contribution of fetal deaths before 20 weeks' gestational age, (2) estimates of underreporting on the fetal death certificates, (3) proportional allocation of unknown causes, (4) estimates of fetal injuries leading to neonatal death, (5) cases missed pertaining to maternal deaths where there was no delivery, (6) estimates of iatrogenic and trauma-related elective abortion where the maternal trauma initiated the chain of events leading to fetal death, and (7) considerations taking into account that fetuses are exposed for a fraction (9/12 months) of a year. A conservative adjusted estimate is that at least 369 motor vehicle–related deaths occur per year in fetuses at greater than 20 weeks' gestation (H.B.W., unpublished data). This estimate takes into account the reasonable assumptions of a 50% fetal death certificate underreporting rate, approximately 30 neonatal deaths per year from traumatic fetal injury (estimated from national mortality statistics), and 123 missed cases due to maternal death (estimated from age-specific birth rate–adjusted motor vehicle deaths in females).[32] However, this estimate does not account for fetal deaths related to iatrogenic injuries, trauma-related therapeutic abortions, and deaths occurring at less than 20 weeks' gestation. There is not enough available information to form reasonable estimates. With these limitations, it is not unreasonable to presume that fetal death from motor vehicle–related events occurs at a higher frequency than in infants.

There was little evidence that older fetuses (≥24 weeks) have a much

higher mortality rate. Slightly lower counts in fetuses with gestational ages 20 to 23 weeks may be attributed to poor reporting at the younger gestational age groups.[33] The lower counts observed for gestational ages more than 36 weeks is probably a function of fewer eligible cases since 80% of all infants are born at 37 to 41 weeks (full term).[28] Thus, all gestational age groups examined shared a substantial risk.

The high geographic (state) variation we observed can be attributed in part to small numbers of deaths per state and unstable rates. Other possible contributing factors include differences in reporting or coding, maternal risk-taking behavior, geographic and seasonal/climatic factors, social and cultural issues, and variations in maternal driving behaviors and seating positions.

In our study, assaults accounted for a small proportion of cases, in contrast to recent reports of homicide as a leading cause of pregnancy-associated maternal deaths.[34-36] Several reasons might explain this difference. First, many studies of pregnancy-associated mortality have been derived from highly urbanized areas such as New York, Chicago, Maryland, and the District of Columbia[34,36-38] where homicide rates are high relative to motor vehicle deaths. When pregnancy-associated maternal deaths have been examined more broadly, the proportion of deaths due to motor vehicle crashes is about equal.[39-45] Second, studies based on medical examiner cases may not fully take into account that motor vehicle deaths, especially passenger deaths, are less likely to be referred for autopsy than homicide cases, creating the opportunity for selection bias.[46] Third, "pregnancy-associated" deaths cover a time period of 1-year postpartum and there may be different RRs of homicide and motor vehicle–related deaths during pregnancy compared with the postpartum period. Fourth, the low proportion of assaults may be due in part to selective reporting and the difficulty attributing deaths to such events or some combination thereof. Most firearm-related cases, for example, contained no documentation as to intent and thus were coded, by *ICD* rule, as unintentional. Many of the "intent unknown" firearm-related deaths on death certificates are actually assaults that are not well documented. Nevertheless, even if all firearm-related cases were intentional, unintentional injuries, mostly motor vehicle-related, would still predominate. Also, a focus on fetal death is mainly a focus on maternal morbidity, not mortality, because most mothers survive the trauma that kills the fetus. Events that are highly lethal, such as firearm assaults, would be more likely to be found in maternal mortality studies. When the mother dies before reaching medical care (eg, from a gunshot wound or severe motor vehicle crash) fetal deaths are probably documented by a different group of certifiers (coroners/medical examiners) than when these women reach the hospital (clinicians), or they may not be documented at all. Through combining knowledge of traumatic fetal injury death from mostly nonfatal maternal injury (fetal death certificates) with mortality data, a better picture of fetal traumatic death emerges.

Table 3. Rate Ratio (RR) for Selected Medical Factors, Fetal Deaths Compared With Normal Live Births*

Selected Medical Factors	Frequency (%) Among Fetal Trauma Deaths	Frequency (%) Among US Live Births†	RR of Trauma to Live Births (95% Confidence Interval)
Fever	5 (2.1)	61 850 (1.6)	1.3 (0.5-3.1)
Abruptio placenta	48 (20.0)	22 062 (0.6)	35.1 (26.4-46.6)
Placenta previa	2 (0.8)	12 915 (0.3)	2.5 (0.6-9.8)
Other excessive bleeding	8 (3.3)	21 142 (0.6)	5.8 (2.9-11.7)
Breech/malpresentation	5 (2.1)	146 431 (3.8)	0.5 (0.2-1.3)

*Selected medical factors are shown only for conditions with counts of 5 or more.
†Data from Ventura et al.[28]

Physicians are probably justified when they attribute fetal deaths at greater than 20 weeks' gestation (when spontaneous abortions are rare) to serious trauma that occurred shortly before fetal death, in the presence of related pathology and in the absence of unrelated pathology. But in comparatively milder trauma (falls) or repetitive trauma (interpersonal violence) or when pregnancy is complicated by other factors, determining whether fetal deaths were trauma-related is problematic suggesting that the study cases represent only a proportion of trauma-related fetal deaths. Fetal death may occur for many reasons, acting independently or in synergy with factors such as medications, use of tobacco, alcohol, and other drugs, fetal or maternal diseases, iatrogenic injury, obstetrical complications, and others.[47] Without specific protocols and large-scale epidemiologic studies, relating maternal trauma to fetal death will continue to rely on medical judgment.

This study was also susceptible to the limitations of the state-based fetal death registration system. While our sample included 55% of the US population, the population was a convenience sample. General concerns that have been raised regarding the quality of fetal death data also apply.[33,48] These include variation by state in the resources and quality of collection and completeness, definitional issues of fetal vs infant death, financial and legal pressures to use or avoid certain descriptions, and lower rates of reporting among the youngest gestational age groups.

To safeguard fetuses, research and information are needed to better understand how to transport pregnant women safely, reduce the crash risk of pregnant women, and reduce other forms of maternal trauma. These measures should consist of (1) incorporating fetal deaths in crash and injury mortality data systems so the problem can be more easily tracked, (2) including several gestational specific models of biofidelic pregnant dummies in government and industry crash tests so the biomechanics and vehicle specific risks can be better understood, (3) adding pregnancy

status variables in government- and industry-sponsored driver behavior surveys so maternal driver behaviors (eg, frequency, seating positions, changes during and after pregnancy) can be better understood, (4) conducting comprehensive crash investigation studies involving fetal deaths to generate hypothesis of what hazards are of particular concern, (5) conducting research on nonfatal fetal outcomes looking at short- and long-term impacts of trauma on multidimensional measures of fetal, infant, and child well-being, and (6) conducting prevention research to develop effective models for decreasing crash and assault risk for pregnant women.

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Analysis and interpretation of data: Weiss, Songer, Fabio.
Drafting of the manuscript: Weiss.
Critical revision of the manuscript for important intellectual content: Weiss, Songer, Fabio.
Statistical expertise: Weiss, Fabio.
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Dedication: This article is dedicated to the families who have suffered through trauma and the immense loss of their dreams while balanced on the threshold of a new life. Though this solace cannot replace what they have lost, the vital public health records left behind by their tragic experiences bequeath a living legacy of knowledge and comprehension.

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