



# The epidemiology of traumatic injury-related fetal mortality in Pennsylvania, 1995–1997: the role of motor vehicle crashes<sup>☆</sup>

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Received 17 March 2000; received in revised form 23 May 2000; accepted 28 June 2000

## Abstract

**Methods:** Rates and causes of traumatic injury-related fetal deaths in Pennsylvania were determined from a manual review of all fetal death certificates filed from 1995 to 1997 (7131 cases). **Results:** Thirty one traumatic injury cases were identified (6.5/100000 live births). Most cases (94%) could be identified from the diagnosis code of 760.5 (maternal injury) and 87% contained narratives indicating specific injury mechanisms. Motor vehicles were the leading cause of injury (81%). Placental separation was the leading diagnosis (42%). **Conclusions:** The ICD-9-CM code 760.5 appears to be a specific indicator of traumatic fetal death, though it is not known how sensitive an indicator it is. Though not usually E-coded, the death certificates contained enough information to allow ascertainment of injury mechanism. These are very conservative estimates of the burden of the problem. The major role that motor vehicle injuries have on reported traumatic fetal injury deaths was shown and a significant new challenge for child passenger safety advocates is indicated. © 2001 Elsevier Science Ltd. All rights reserved.

**Keywords:** Fetal mortality; Maternal injury; Motor-vehicle

## 1. Historical context

The effects of traumatic injury on pregnancy have been observed for millennia. While the oldest cases are lost in the fog of antiquity, known instances are referenced in the 15th century BCE Code of Hammurabi (Buchsbaum, 1976) and the Old Testament (Exodus 22:21).

In the medical literature of the late Nineteenth and mid-Twentieth centuries, the issue received increasingly detailed coverage, primarily in the forms of case reports and series. While the earliest of these papers described incidents pertaining to falls, 'blows' and assaults (Brinton, 1884), as society mechanized and automobile use expanded, clinical reports increasingly

contained references to automobile related incidents.

Woodhull referred to one of the earlier known motor vehicle-related fetal deaths in 1940 (Woodhull, 1942). A 20-year-old, 7-month pregnant woman was ejected from a vehicle with fetal death reportedly due to uterine rupture. In another early report a 21-year-old pregnant woman was involved in a head-on automobile collision resulting in a fractured pelvis and subsequent fetal death due to fetal skull fracture (Seear and Woeppel, 1953). Dyer and Barclay (1962) reported a case series of 53 pregnancy related trauma cases in which 30 were automobile-related, five were from penetrating wounds, 13 were from falls and three from assaults. In 1960–1961, Peckham and King conducted a prospective study of 3072 pregnancies in women enrolled in a single health maintenance organization in Northern California and reported a 7% (214/3072) rate of maternal injury during pregnancy (Peckham and King, 1963). The leading maternal injury causes were falls and motor vehicle-related injuries and to a lesser extent cutting and piercing injuries and assaults. Fetal outcome was not a focus of this study.

<sup>☆</sup> An earlier version of this paper entitled 'The epidemiology of traumatic injury-related fetal mortality in Pennsylvania: the role of motor vehicle crashes' was presented at the meeting of the Association for the Advancement of Automotive Medicine, Barcelona, Spain, September, 1999.

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## 2. Modern scientific foundations

By the mid-1960s, within the trauma and obstetrics communities, the problems and challenges of pregnancy and automotive crashes were well recognized. Estimates of fetal mortality rates based on case series were increasingly reported (Elliott, 1966; Buchsbaum, 1968; Crosby and Costiloe, 1971). The first experimental (animal) studies investigating the forces and physiology of restrained pregnant women were initiated in 1968 (Crosby et al., 1968). Crosby was also the first to conduct a follow-up study of pregnant occupants involved in (rural) crashes (Crosby and Costiloe, 1971). The study followed 208 pregnant victims of severe crashes, focusing on studying the effects of lap-belts. It pointed to the benefits of lap restraint for both the mother and the fetus. Crosby also identified placental separation as a leading cause of fetal death among maternal survivors (six of 14 fetal deaths with maternal survival) (Crosby and Costiloe, 1971).

Since the 1970s, more than 30 hospital-based case series of fetal outcome following maternal trauma have been published (Pepperell et al., 1977; Rothenberger et al., 1978; Oni et al., 1984; Rose et al., 1985; Esposito et al., 1989; Timberlake and McSwain, 1989; Pearlman et al., 1990a,b; Klinich et al., 1998). However, these studies used varying definitions for case inclusion criteria and did not use population-based methods. When these factors are combined with the relative rarity of fetal deaths, it becomes difficult to aggregate these studies in a usable fashion to describe fetal deaths from a valid meta-analysis or epidemiological perspective, or to produce reasonable estimates of population-based rates. Those who have attempted such meta-analyses report wide national estimates of the numbers of fetal deaths due to maternal car crash involvement; ranging from 1300 to 13000 deaths/year (Pearlman and Phillips, 1996; Pearlman, 1997).

Far fewer studies have approached the issue from the perspective of fetal mortality, i.e. ascertaining traumatic injury-related fetal deaths and looking back to see what happened; as opposed to identifying maternal injuries and looking forward. Those that have studied the issue from a fetal mortality perspective only focused on motor vehicle-related injuries ascertained through coroners offices (Agran et al., 1987; Stafford et al., 1988; Lane, 1989) thus making it impossible to assess the relative contribution of motor vehicle-related fetal deaths compared to other events. Yet, these studies were based on defined geographic populations. Agran et al., (1987) reported on a series of nine coroner cases from a Southern California county of fetal motor vehicle-related deaths. They were the first to realize that fetal crash related deaths might be an important cause of motor vehicle-related

fatalities among children. They reported that fetal motor vehicle-related deaths occurred at a higher mortality rate than that for children 14 or younger involved in motor vehicle accidents. Lane published a population-based series of motor vehicle-related third-trimester fetal deaths reported to the Ontario Canada Chief Coroner's Office from 1982 to 1986 (Lane, 1989). An incidence of two motor vehicle-related fetal deaths per 100000 live births was found.

In the broader fetal death and stillbirth epidemiology literature, few reports separate trauma as a cause. Naey (1977) reported that the rate of 'trauma to gravida' resulting in stillbirth was nine per 100000 births, ranking 24th among known causes. This was not a population-based study because the data were collected from 12 'University affiliated hospitals in different regions'. It also included cases from 20 weeks of gestation up to 28 days after birth.

## 3. Government statistics: fetal death registries and crash reporting systems

In contrast to the widespread awareness of the issue in the medical community, traumatic injury-related fetal mortality has received little attention from the public health vital statistics infrastructure or from modern traffic injury or crash data systems. In the former, coding conventions have limited examination of the cases to a grouping called 'death due to maternal injury'. This subgroup is often combined into an even broader category of 'maternal causes'. Thus, contributions of injuries in fetal death reports are usually not discernable (Herschel et al., 1995; Bausch and Smith, 1996; Rasmussen et al., 1996; American Academy of Pediatrics & the American College of Obstetricians and Gynecologists, 1988). Further, because the International Classification of Disease (ICD) diagnosis code used to denote death due to maternal injury (760.5) is neither an E-code (external cause) nor in the range of codes traditionally included in case definitions by injury researchers, such cases have gone unreported in all state and national injury data compendiums. In crash injury data systems, fetal deaths are simply excluded from the case definition of an injured person.

Without ongoing case ascertainment and population-based surveillance, the true magnitude of the problem, who is at risk, what kinds of trauma carry the highest risk and whether the problem is increasing or decreasing, will remain unknown. Without a basic understanding of the epidemiology of traumatic injury-related fetal mortality, it is difficult to develop and evaluate effective prevention strategies.

### 3.1. *The utility of State Fetal Death Registries*

Most state health departments maintain fetal death registries (Kowaleski, 1997) of varying accessibility. Federal guidance has led to the adoption in most states of the 1992 Revision of the Model State Vital Statistics Act and Regulations which uses a definition of fetal death promulgated by the World Health Organization (National Center for Health Statistics, 1992). Fetal death registry systems are modeled after death certification systems. Like the standard death certificate, the fetal death certificate contains sections for identifiers, other demographic information, and narratives on the cause of death. In addition, it contains sections on pregnancy risk factors similar to the information collected on birth certificates. In most states, fetal deaths of 20 weeks or more gestation are required to be reported (Kowaleski, 1997).

Unfortunately, like most other states, Pennsylvania does not create a multiple cause-of-death file for fetal deaths; only a single underlying cause can be searched for in the computerized file. More importantly, because of coding guideline practices, the external cause codes that normally categorize underlying external causes of death that are routinely used in standard death registries, are rarely, if ever, used in fetal death registries. Instead, the coding guidelines are based on the premise that in most cases it is the mother who is injured, not the fetus. Rather than code fetal deaths to external causes such as a motor vehicle crashes, coding conventions require coding fetal deaths as due to maternal injury (760.5) with no other codes for the specific cause of the maternal or fetal injury. Therefore, to glean details on the mechanism of maternal injury and fetal death, it is necessary to examine fetal death certificates; computerized abstracts do not suffice.

In Pennsylvania, fetal deaths greater than or equal to 16 weeks gestation are required to be reported to the State on a standard form. Usually, hospitals and to a lesser extent coroners, do the actual reporting. The fetal death certificates are sent to the State Vital Statistics Office where they are coded and keyed, microfilmed and stored. The current study was based on these reports.

## 4. Methods

Fetal death certificates sent to the Pennsylvania State Health Department covering the years 1995–1997 were reviewed. Published reports indicated that there were 7131 fetal death certificates filed (among 442705 live births) during this period. After internal review board approval and an approval for access to protected data from the state Health Department, arrangements were made to visit the Division of Vital Records for certifi-

cate review and data abstraction (without the use of identifiers or patient follow-up).

### 4.1. *Inclusions and exclusions*

A limited case definition and several categories of exclusions were applied. Included were cases where a fetus was directly or indirectly affected as a result of an in-utero traumatic injury to itself or the mother (excluding birth-related trauma and abortion), and where the fetus died before birth. A fetal injury could occur and the baby be born and then die, but these cases are not found in the fetal death records. Other exclusions included: therapeutic abortions; fetal deaths due to a history of maternal surgery; fetal deaths due to maternal or fetal injuries if they occurred more than 30 days prior to death; medical misadventures; elective termination of a conception that arose after a rape; drug, cigarette and alcohol exposures; umbilical cord accidents; diethylstilbesterol (DES) exposure; amniocentesis; fetal asphyxia; radiation; and heavy metal poisonings.

### 4.2. *Record review procedures*

The review was conducted by looking for any trauma-related conditions noted on each of the fetal death certificates. Immediate and underlying causes were examined for the 'fetal or maternal conditions directly causing fetal death'. Other significant conditions possibly contributing to fetal death, and other narrative fields found under the 'Medical and Health Information' section of the fetal death certificate were also reviewed.

Two death certificate reviewers worked side-by-side for approximately 10 days, reviewing 7131 certificates. If either reviewer had a question about legibility or applicability of a certificate narrative, they discussed it and immediately reached a consensus. Illegible medical risk factors were ignored in cases with indeterminate or unknown causes. This was not a major factor as only four certificates had illegible immediate causes or other significant conditions, making up less than 0.1% of all certificates. Both reviewers had considerable experience reviewing medical records and both were doctoral candidates in epidemiology.

One case with placental pathology had a narrative of 'history of domestic abuse' listed in the 'other risk factor' section. This case was excluded on the conservative judgment that the abuse may or may not have been physical and because the narrative was not placed in the 'immediate' or 'underlying cause' section. One other case excluded listed the underlying cause as 'traumatic rupture of the amniotic sack'. While the term 'traumatic' would seem to warrant inclusion, it was thought that this term could also be applied to rupture caused

Table 1  
Summary of findings from review of Pennsylvania Fetal Death Certificates: 1995–1997

Characteristic	No.	% of all Traumatic Injury FDC	Rate per 100 000 live births
Total number of manually reviewed Fetal Death Certificates (FDC)	7,131	–	1505
Number of identified traumatic injury cases	31	100	6.5
Number of traumatic injury cases reported as <20 weeks gestation	4	13	–
Cases coded in computerized file as 760.5 (maternal injury)	29	94	–
Cases with mechanism of injury mentioned somewhere on FDC	27	87	–
Number of cases with mention of motor vehicle involvement	25	81	5.3
Cases with placental separation listed as a diagnosis	13	42	2.7
Cases with uterine rupture listed as a diagnosis	4	13	0.8

by a weakening of the sack with unknown etiology or strong internal fetal movements, as opposed to an external force. In the absence of any corroborative evidence of an external force, the case was omitted.

As a quality control procedure, each manually identified maternal injury case for the first 2 years was checked against a 2-year computerized listing of all 760.5 coded cases. All 17 of the computer-listed cases were properly identified by the manual review.

## 5. Results

Table 1 summarizes the major findings from this review. There was little difference between fetal gender (15 males, 12 females). The mean maternal age was 25 years, with the distribution skewed towards younger ages (Fig. 1). Seventy-seven percent of the mothers were white and 19% were black (blacks represented about 15% of all live births in Pennsylvania in 1995). Eleven of the deaths occurred in 1995, seven in 1996, and 13 in 1997. In three of the cases (10%), the fetal death certificate noted the death of the mother.

All four of the uterine rupture cases were associated with a motor vehicle crash. The average gestational age of three of these cases (one case was missing gestational age) was 34.7 weeks, compared to 27 weeks for cases without mention of uterine rupture. Among the 13 cases with mention of placental abruption 11 (84.6%) were associated with a motor vehicle crash.

Fig. 2 shows the distribution by mechanism of injury. Over 80% of the cases had narrative evidence indicating a motor vehicle crash as the mechanism of injury. The mean gestational age for the 22 motor vehicle-related cases that had a gestational age listed was 28.3 weeks (range 16–40 weeks, S.D. = 8.1).

## 6. Discussion

This study probably represents the largest reported population-based description of traumatic fetal injury-

related deaths to date. By far, the leading cause of traumatic fetal injury death was motor vehicle crashes. Placental separation was the leading physiologic injury diagnosis. The rate of overall reported traumatic injury-related fetal death ( $\geq 16$  weeks gestation) was 6.5/100000 live births, slightly lower from the nine reported by Naey (which used a slightly different definition and drew cases mostly from tertiary care centers). Applying the death rate observed in the current study to the US population suggests that at least 200 traumatic fetal



Fig. 1. Maternal age frequency histogram for all traumatic fetal deaths, Pennsylvania, 1995–1997.

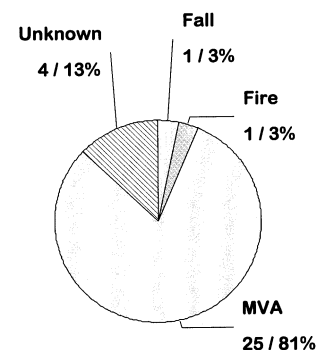


Fig. 2. Injury mechanism for all traumatic fetal deaths, Pennsylvania, 1995–1997.

injury deaths ( $\geq 16$  weeks gestation) may occur annually.

The ICD-9 code '760.5' was shown to be a very specific indicator of fetal trauma since more than 90% of the cases upon manual review were coded as '760.5'. Most of the '760.5' coded death certificates contained enough additional information with which to ascribe and make feasible the independent coding of the injury mechanism and often the underlying physiological cause of injury. However, it is not known how sensitive an indicator this code may be since many other death certificates are coded with underlying causes such as placental abruption and other conditions that may have been related to a traumatic injury, but also may have some other known or unknown underlying cause. Undercounting was possible.

How much undercounting (false negatives) and what biases may be inherent in cases missed by the ascertainment method used in this study can only be speculated upon. Maternal deaths in the early stages of pregnancy may not always be identified and noted unless autopsies are conducted. Fetal deaths with gestational ages  $< 16$  weeks were missed completely because of reporting exclusions. Traumatic events that lead to observed fetal death several days or more after the event, or events of minor maternal severity, may be less likely to be ascribed to maternal injury and reported. The methodology reported here, based only on fetal death certificates, cannot detect cases of fetal injury leading to a live birth and subsequent infant death. The author has looked at this issue (details not reported here) and has found an average of at least 40 such deaths each year in the US multiple cause of death file (Weiss, 1999). Therapeutic abortions, common in severe maternal trauma, are not counted (Sorenson et al., 1986; Kissinger et al., 1991; Scorpio et al., 1992). Lastly, it is unknown whether possible hospital or physician reporting biases may selectively accompany self-inflicted or intentional injury events or otherwise impact on the adequacy of the documentation used to code the deaths.

The extent of possible over counting (false positives) is also difficult to measure. Ultimately, the mention of a traumatic injury as an underlying or important contributing cause on a fetal death certificate is a clinical decision similar to the way many if not most other causes are recorded on death certificates. As there are no detailed, rigorously established guidelines in widespread use with which to guide such clinical and forensic determinations for traumatic fetal injury-related deaths, these estimates must be thought of as being derived from imprecise but the best available practices.

With contemporary concerns about airbag safety, decreases in most other causes of maternal mortality and perinatal mortality, and increasing attention being paid to women's health issues, interests regarding the

impact of motor vehicle crashes to pregnant women and their fetuses have been mounting. The major role that motor vehicle injuries have on reported traumatic fetal injury deaths is shown. The rate of fetal deaths related to motor vehicle crashes for Pennsylvania in 1995–1997 was estimated at 5.3/100000 live births. This is double the rate reported by Lane for Ontario for 1982–1986, probably because of the inclusion of younger gestational ages in the current study. This rate is, however, eight times less than the lower bounds of other estimates in the literature derived from non-population-based methods.

This study suggests that the annual number of motor vehicle-related fetal deaths ( $\geq 16$  weeks gestation), estimated to be at least 160 cases/year in the US, is on par with the annual number of MV related infant deaths in the US, which averages 178/year. When one takes into account the possible under-reporting of fetal injury deaths, the difficulty of ascribing stillbirths to minor trauma, undocumented fetal morbidity from similar events in which the fetus survives, and the fact that some reported infant deaths are due to injuries suffered in utero, fetal deaths due to motor vehicle crashes becomes an important but under-recognized area for traffic safety and injury control.

## 7. Recommendations

This study should be expanded to include examination of traumatic injury-related fetal deaths across the country to garner more numbers for analysis and better geographic representation. The author is currently engaged in such an effort and results from an analyses of birth certificates coded as 760.5 from states representing about 50% of the US population of women of childbearing age over a 3-year period (1995–1997) will be submitted for publication in the near future. About 240 fetal death certificates will be reported in this expanded study.

Additional recommendations include the following: a national and international effort should be initiated to improve the cause coding (E-coding) of fetal death certificates; documentation of pregnancy should be improved in such data sources as death certificates, trauma registries, and crash data systems; there needs to be more in-depth investigation of crashes leading to fetal death to look at crash, vehicle, maternal, fetal, and medical care factors; the reporting of fetal injury deaths should be included in state and national injury mortality and crash reporting system publications so that the problem is better publicized and followed; Lastly, more efforts to ensure that pregnant women use safety belts and properly use them should be initiated.

## Acknowledgements

Partial funding for this project was supplied by the National Highway Traffic Safety Administration through a grant with the University of Pittsburgh Graduate School of Public Health Department of Biostatistics. I would like to thank my research assistant, Tony Fabio, for his help in data collection and abstraction and my colleagues at the Center for Injury Research and Control for their review and comments on manuscript drafts. This work was contingent upon the helpful cooperation of the Pennsylvania State Department of Health, specifically the Division of Vital Records. The Department specifically disclaims responsibility for any interpretations or conclusions in this report.

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