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The National Association of Medical Examiners (NAME) position paper on the investigation and certification of fetal demise, stillborn, and early neonatal deaths

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ABSTRACT:

Perinatal deaths (including fetal death (FD), miscarriage, stillbirth, and early neonatal death (ENND)) referred for forensic investigation are often complex and can involve medical, biological, traumatic, toxicological, and psychosocial components. Further complicating these deaths is the regional and national heterogeneity of statutory requirements, practice conventions, and access to resources. This inconsistency affects the quality of national data and may impact mothers and families by potential criminal prosecution and/or loss of parental rights. Thus, the National Association of Medical Examiners (NAME) convened an expert panel to create a position paper regarding the investigation of perinatal deaths. This paper provides evidence-based guidance to medical examiners, coroners, and death investigators regarding the investigation and certification of perinatal deaths, with specific focus on the settings of maternal substance use disorder and making the determination of live birth versus stillbirth.

INTRODUCTION

Perinatal deaths (including fetal death (FD), miscarriage, stillbirth, and early neonatal death (ENND)) referred for forensic investigation are often complex and can involve medical, biological, traumatic, toxicological, and psychosocial components. When deliveries occur outside of medical care, a key question may be whether a stillborn fetus or a live neonate was delivered. Further complicating these deaths is the regional and national heterogeneity of statutory requirements, practice conventions, and access to resources [1]. This inconsistency affects the quality of national data on these deaths; furthermore, it may impact mothers and families by potential criminal prosecution and/or loss of parental rights.

The National Association of Medical Examiners (NAME) convened an expert panel of authors to create a position paper that provides recommendations for the investigation, autopsy, and certification of these deaths.

The group identified three questions of importance:

1. What are the indications for taking jurisdiction and performing autopsies of fetal and neonatal deaths?
2. What is the impact of maternal substance use on fetal and neonatal deaths, and how are the deaths investigated and certified?
3. What tools, findings, tests, or combination thereof, are useful to help distinguish a liveborn neonate from a stillborn fetus?

BACKGROUND:

Fetal death is one of the most common adverse pregnancy outcomes, affecting around 1 in 175 births each year in the United States (U.S.), or around 20,000 births annually [2]. Both fetal deaths and live births are events registered by civil registration systems for inclusion in vital statistics due to their public health value and impact on individual families. Globally, this recommendation to register vital events is

set by the United Nations Statistics Division (UNSD), which is mandated to establish global standards for civil registration and vital statistics systems [3]. In the U.S., which has a federated civil registration system, each of the 50 states and seven jurisdictions is responsible for the registration of stillbirths and live births, which it reports to the Center for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS) for the cooperative production of vital statistics [4]. There is still variability, however, in the definitions used by different agencies or jurisdictions, and in the regional or state statutes governing which deaths must be reported to a Medical Examiner or Coroner (ME/C) [1]. This impacts the quality of vital statistics.

Since fetal deaths and live births are health outcomes, the World Health Organization (WHO) defines these vital events through the International Classification of Disease (ICD), a nomenclature it is mandated to maintain as per the WHO Constitution [5]. Although the U.S. has adopted the WHO ICD definition of fetal death [6], it uses a slightly broader definition of stillbirth than the WHO and sets the gestational age at 20 completed weeks gestation in the Model State Vital Statistics Act and Regulations adopted by most states [4] (**Table 1**). Of note, "stillbirth" is still a commonly used term, and is also the term preferred by parent groups [7]. However, the broader term of "fetal death" (FD) is used in this publication to encompass all fetal deaths that may be reported to and investigated by an ME/C, including those that occur prior to 20 weeks of gestational age (i.e., "miscarriages") and those that occur after 20 weeks of gestational age (i.e. "stillbirths").

In the U.S. the standard reporting forms for births, fetal deaths, and deaths are produced by NCHS in collaboration with states. The U.S. Standard Certificate of Live Birth and the U.S. Standard Report of Fetal Death, last revised in 2003 and adopted by most states by 2018, are used to report live births and fetal deaths for their registration, respectively [8] (Figure 1). A key component of the U.S. Standard Report of Fetal Death is the reporting of the cause of death which can be used for public health program planning to prevent stillbirths. According to CDC guidance developed with the 2003 revision of the U.S. Standard Report of Fetal Deaths, cause of death is the certifying physician's best medical opinion of the cause or condition that triggered a sequence of events resulting in the fetus' death [9]. In the case of stillborn fetuses, conditions of the fetus, mother, and/or placenta (including the umbilical cord and membranes) are appropriate to report if the physician deems them to be part of the causal sequence resulting in fetal death. To ensure consistency in classifying vital events across U.S. jurisdictions and globally, clearly defined terms are important to use. Of note, some states (including California and Rhode Island) have modified their fetal death certificate to include manner of death, a field which is not present on the U.S. Standard Report of Fetal Death [10, 11].

METHODS:

Electronic literature searches were performed on PubMed for articles available in the English language without limitations on publication date. Relevant publications (to include position papers or guidance from world and national organizations) were also shared from the individual authors' collections.

Search terms used included: stillbirth; intrauterine fetal demise; forensic pathology; autopsy; lung float test; docimasia; live birth; neonaticide; maternal drug use; and substance use disorder.

DISCUSSION

Question #1: What are the indications for taking jurisdiction and performing autopsies of fetal and perinatal deaths?

While certain fetal and neonatal deaths (e.g., traumatic) are best investigated by a medical examiner or coroner (ME/C), others are more suitable for a hospital autopsy overseen by a non-forensic pathologist (preferably a perinatal or pediatric pathologist). If there is a question of liveborn versus stillborn, the ME/C is typically involved. Acceptance of jurisdiction in these deaths can be complicated, controversial, and occasionally even political. While some medicolegal authorities are required to investigate certain fetal and neonatal deaths by state or local statute, others instead rely on office policy or other criteria [1].

A 2024 survey investigated the practices of forensic pathologists across the U.S. regarding perinatal deaths. The criteria used by respondents to accept jurisdiction of a known or suspected stillborn fetus were variable and included: a) history of maternal trauma, b) non-medically supervised out-of-hospital birth, c) history of maternal drug use, d) suspected illicit termination of pregnancy, e) if the death was a complication of medical therapy, f) need for DNA collection in a potentially sexual assault-related pregnancy, g) autopsy request by family, h) gestational age or weight, i) absence of prenatal care, or j) at the request of the district attorney, law enforcement, or medical providers [1].

Given the regional variation in legislation, one cannot set absolute rules regarding when a medicolegal investigation must be performed. However, professional recommendations can be made for those regions which have flexibility to determine which cases to investigate. Despite these regional differences, 86% of surveyed forensic pathologists agreed that a fetal death with a history of maternal trauma would fall under the jurisdiction of the ME/C, and 68% agreed that a non-medically supervised out-of-hospital birth (e.g., a suspected fetus or neonate discovered in a garbage can) would fall under ME/C jurisdiction [1]. In such instances, the gestational age is generally not considered in terms of whether to accept jurisdiction. Contrarily, fetal death when there has been adequate prenatal care or when there is a known fetal malformation with death as the expected outcome, may not necessarily fall under medicolegal jurisdiction.

To that end, obtaining information about the circumstances of the death and the maternal medical history is crucial to determine whether it is appropriate for the ME/C to accept jurisdiction. If accepted, additional investigation should be performed. This includes a) a scene investigation of where the fetus was discovered and where pronounced dead (if different) with photographs and videography documentation, if available, b) medical records including emergency medical service or first responder reports pertaining to the death, c) medical records regarding the extent of maternal prenatal care, if any, and d) information about any known complications of previous pregnancies.

The analyses listed in **Table 2** may be helpful in determining the cause of death. Unfortunately, limited resources in some areas, including personnel and funding, may hinder the extent of examination. Autopsy examination of a fetus/neonate should document a) presence or absence of maceration, and the degree to which it is present [12-14], morphologic measurements for estimating gestational age (**Table 3**) [15], c) evaluation of physical maturation (**Table 4**) [16], d) presence or absence of gastric content, and the amount and consistency if present, e) the quality and color of the lungs, and f) examination of the placenta or review of the placental surgical pathology report [17]. In cases where the placental findings are critical in determining the cause of death, live birth, or carry the potential for criminal charges, consultation by a board-certified pediatric pathologist is prudent.

If the fetal/neonatal death is determined not to fall under the jurisdiction of the ME/C, or if jurisdiction is declined by the office, a hospital autopsy may be performed with family permission. In some circumstances, a hospital autopsy is preferable, as it may offer the opportunity for additional testing (e.g., fetal karyotype, postmortem genetic testing, or immunohistochemistry) which might be difficult to access in a forensic setting. This is particularly true of deaths related to suspected natural diseases (whether genetically mediated or otherwise). The hospital autopsy also allows for direct observation by perinatal clinical teams who may have been caring for the mother and her fetus or neonate. The U.S. Standard Report of Fetal Death contains information about the mother's social history, health and medical information, prenatal care, and the circumstances of the delivery, all information that is known by the obstetrician, midwife, or other medical provider who cared for the mother while she was pregnant and during the delivery. It also includes the findings of the examination including the placenta, membranes, cord, and fetus, all information that is known by the pathologist who performed the examination. If an autopsy is not performed, the clinician is responsible for completing the death certificate. If an autopsy is performed, either in the hospital or in an ME/C Office, the clinician and pathologist ideally would confer and share information to complete the death certificate. If the pathologist completes the form without clinical background, or the clinician completes the form without autopsy results, the information may be incomplete and/or inaccurate.

Question #2: What is the impact of maternal substance use on intrauterine and perinatal deaths, and how are they investigated and certified?

It is relatively common for fetal and neonatal deaths to be referred to a ME/C when it occurs in the context of maternal substance use disorder (SUD) [18, 19]. Substance use during pregnancy has been associated with poor outcomes including stillbirth, placental abruption, and restricted fetal growth [20-25]. However, this association is confounded by the common co-occurrence of other factors, particularly tobacco use/smoking, alcohol use, lack of prenatal care, racial and ethnic disparities in pregnancy outcomes, poverty, and other social determinants of health,which increase the risk for adverse outcomes [21, 23, 26-31]. Further evidence of this complex relationship comes from studies which note improved pregnancy outcomes for women with SUD when provided with improved levels of prenatal and/or addiction care [32, 33]. Further complicating these cases is the potentially limited quantity and quality of specimens which can be collected during fetal autopsy, which may create challenges when performing and interpreting toxicology testing. While not substances which are typically abused, on occasion there may be concern regarding possible use of abortifacient medications. Although some research has demonstrated the ability to detect certain medications, at the time of writing there are no clinical or forensic laboratories in the U.S. providing routing testing for these substances [34, 35]. Microcrystalline cellulose and crospovidone have been identified microscopically in placentas following high-dose vaginal administration of misoprostol, but these are common filler materials and therefore cannot be considered diagnostic [36].

Evidence of specific placental pathology induced by chronic maternal SUD is lacking [37]. Proposed mechanisms of the poor pregnancy outcomes associated with SUD include decreased placental vascularization [38], epigenetic modification of the placenta [39], and altered placental size/growth [40]. These are all chronic processes and have not been distinguished from the effects of the potentially confounding variables described above.

Placental abruption has been associated with maternal SUD [22], and stimulant use has long been associated with increased risk of placental abruption [22, 41-44] with acute vasoconstriction representing a potential mechanism in such cases. Although many factors are associated with abruption, the factors that have the greatest risk include previous abruption, chronic hypertension, preeclampsia, cocaine and other illicit drug use (range of relative risk 4.0-8.0), and intimate partner violence [45]. Studies are, however, limited by confounding variables [46]. Additionally, current literature suggests the underlying risk for placental abruption develops early in pregnancy, resulting from a combination of vascular underperfusion, inflammation, infarction, and/or thrombosis. The pathophysiology of abruption therefore may involve long-standing chronic processes, acute “triggers”, and the interaction between the two [45].

As the effects of acute and chronic substance use on the placenta and developing fetus are complex and intertwined with socioeconomic determinants of health, some have proposed that maternal SUD is more accurately classified as a chronic disease[19]. To acknowledge the uncertain and complex relationship, one can use “in the setting of maternal substance use disorder (tobacco and cocaine)” in the cause of death statement to avoid the terms “acute intoxication” or “toxicity”. In contrast to the typical death certificate, the U.S. Standard Report of Fetal Death (**Figure 1**) does not have a specific “cause of death” field and instead lists a series of checkbox items. This can occasionally cause difficulty with translating a narrative cause of death statement into the format required for the form. However, there are free-text fields which can be used to ameliorate this problem. For example, a certifier could write “in the setting of maternal substance use disorder” in the field “Maternal Conditions/Diseases”. This terminology provides important public health information while avoiding potential misinterpretation by non-medical entities who may review the autopsy report, verdict, and/or cause of death statement.

Designating a manner of death in these situations may be required in the setting of fetal death, for those in jurisdictions using a modified fetal death certificate. However, even in jurisdictions using the U.S. Standard Certificate of Fetal Death, manner of death may be required if an infant is born alive yet subsequently dies from complications of prematurity. As the effects of maternal SUD on the fetus are typically chronic in nature, rather than related to an acute toxicity/intoxication, these deaths are best classified as "natural" [1, 47, 48]. An exception to this would be in the setting of maternal death or near-death due to acute intoxication – as the maternal circulatory system is the life support unit for the fetus, maternal death (or cardiac arrest with resuscitation, for example) may result in stillbirth. As described earlier, there is still an uncertain relationship between acute stimulant intoxication and placental abruption, and whether the stimulant may act as an acute precipitant of abruption. Because of this uncertainty, a manner of either "undetermined" or "accidental" may be appropriate. Examples of suggested wording and manners are included in **Table 5**. Of note, if the certifier lives in a jurisdiction where manner of death is not required for certification, it is recommended that the certifier not opine on manner of death in the autopsy report, case management system, or elsewhere.

Question 3: What tools, findings, tests, or combination thereof, are useful to help distinguish a live birth from a stillbirth?

A liveborn infant may be distinguished from a stillborn fetus by the process of postmortem investigation. There is, however, only one autopsy finding that is indisputably diagnostic of livebirth (food in the stomach), and one autopsy finding highly supportive of stillbirth (maceration). Otherwise, the determination is based on a combination of circumstances and pathological and radiographic findings. As this determination may result in criminal charges, one needs a higher standard than just probable [49].

It is worth noting that the definition of a live birth from the U.S. CDC does not require breathing. "…[A]ny other evidence of life" (to include a heartbeat, pulsations of the umbilical cord, or "voluntary" movement) is also sufficient [6]. Therefore, while forensic pathologists commonly look for surrogate evidence of post-delivery breathing at autopsy, a "negative" result does not entirely exclude the possibility of a live birth. There is relatively sparse literature regarding the various methods used to diagnose live birth, and available studies are hampered by small sample sizes or lack of rigorous methodology. The following is a review of these factors with a discussion of their usefulness and reliability as well as warnings about confounding elements.

Factors to Consider

Food in the stomach

Curdled milk in the stomach (or lungs from gastric content aspiration) is essentially diagnostic of a liveborn infant [50]. Interestingly, a recent survey showed 13% of forensic pathologists responded that this finding did not help distinguish liveborn infants from stillborn at autopsy [1]. This may reflect the rarity of this finding in practice rather than its diagnostic accuracy. It is theoretically possible to infuse milk through a nasogastric tube into a dead infant, but this would be exceedingly unlikely outside of a hospital setting. As an important caveat, the pathologist should be certain the material represents food (i.e. milk or formula), and not chyle or a mixture of meconium and amniotic fluid.

Maceration

Maceration is a form of decomposition involving the sterile autolysis of the body after death [50]. Autolysis is the self-dissolving of tissues and is grossly manifested by epidermal-dermal separation ("skin slippage"), a pink or red skin color change, and softening of the internal organs causing changes such as overriding of the skull plates [49]. The process of maceration is different from that of putrefaction, which is a process driven by microorganisms that reside in and on the living body. During life, these organisms are kept

in check by the immune system. After death, they proliferate and spread throughout the body, resulting in bloating, green discoloration, marbling, foul odor, and skin slippage.

The gastrointestinal tract remains sterile after delivery until the infant ingests microorganisms (typically by feeding), allowing the bacteria in the food to colonize the gastrointestinal tract. Unless there is an intrauterine infection (e.g., chorioamnionitis, maternal sepsis), the fetus resides in a sterile environment. Therefore, if a fetus dies in utero without exposure to an infectious agent, they will undergo autolysis ("maceration") and not putrefaction. It is important to note, however, that autolysis is also a component of typical decomposition that occurs in any death, including infants who die shortly after birth [51]. Autolysis includes focal skin slippage and pink discoloration, and it may be seen in liveborn infants who die and are subsequently not properly refrigerated after death. Therefore, interpreting intrauterine maceration from post-delivery autolysis of a liveborn infant may be challenging. These skin changes also may be seen with certain infections that occur during life (e.g., scalded skin syndrome) and with scald injury. Additionally, while maceration is highly supportive of fetal death, it is not always present when the interval from fetal death to delivery is short.

The forensic pathologist can interpret the autolysis by considering the circumstances of death and other autopsy and placental findings. Experimental attempts to "age" maceration in known stillbirths have been attempted with little success [52, 53]. One consideration is the reputed time between delivery and the first examination of the decedent [53, 54]. If there is extensive maceration with a well-documented delivery-to-examination interval, one may be able to conclude that the extent of maceration is not consistent with a reputed short post-delivery interval (e.g., two hours). The extent of maceration would support an intrauterine death. A longer interval of 3 days, however, could explain a degree of autolysis which would also support a post-delivery death depending on the exposure conditions.

Temperature also affects the speed at which autolysis and putrefaction occur. Fetal demise occurs in a warm environment (98.6 C) compared to typical environmental temperatures. Thus, a fetus who dies in utero will undergo autolysis more rapidly than a delivered liveborn infant who dies and then remains in a more temperate climate. In general, it takes hours (some reports note at least 6-8 hours) of death in utero before there is gross autolysis [54]. There are studies that have evaluated gross and histologic changes to help determine the postmortem interval but these findings cannot distinguish liveborn from stillborn [12-14].

Lung float/hydrostatic test (docimasia)

The so-called "float test" has a long history of use for distinguishing liveborn infants from stillborn fetuses, beginning in the 17th century [50, 55-61]. The principle is relatively simple, with the rationale that the lungs of a liveborn infant will float in water due to aeration from breathing, while the lungs of a stillborn fetus, absent of air, will sink. The exact description of how the test is performed has changed slightly over the centuries, but it is generally done by removing the heart and lungs en bloc and putting them in water. Cold water, warm water, and rainwater have been recommended, though all descriptions prohibit adding salt to the water [62]. Some recommend noting the speed at which they rise or sink. If the lung and heart block floats, it is recommended that each lung be tested individually, as well as pieces of each separate lobe, both before and after compression. Compression techniques vary from manual compression to standing on a board atop the pieces for complete compression. A piece of liver is suggested as a control to assess for generalized gas formation from decomposition [60]. Most components of this test were developed centuries ago, with only slight variations, yet in the years since its introduction authors have grappled with the interpretation and relative validity of the test itself. Some literature calls for the outright condemnation of the test as unreliable and dangerous [63] while others applaud the test, and its usefulness if certain caveats are taken into consideration. Most of these considerations tend toward the practical and observation based, with few actual clinical studies being done to assess the relative merits.

Each outcome of the test with the relative considerations is considered below:

A “true positive” test result occurs when the lungs of a liveborn infant float. A “true negative” test result occurs when lungs of a stillborn fetus do not float (sink).

“False positive” results (i.e. the lungs of a stillborn fetus float) may arise when external air/gas is introduced to the respiratory and/or gastrointestinal tract, as can occur by attempted resuscitation or by the internal production of air/gas (as in putrefaction) [49].

“False negative” results (i.e. the lungs of a liveborn infant do not float) can arise if the infant, despite being born alive, does not draw sufficient air into the respiratory tract. This can be due to birth into water (such as a toilet bowl or bath), lung pathology (such as hyaline membrane disease), or other congenital anomalies which prevent full respiration, [49].

The largest study investigating the lung float test examined 208 known liveborn neonates or stillborn fetuses in a hospital setting [58].In this series, all 194 stillborn fetuses had lungs that sank; of the 14 liveborn infants, four had false-negatives (i.e., lungs that sank) despite intubation [58]. A mechanism for false-positives (i.e., lungs floating in a stillborn fetus) has been anecdotally proposed - during delivery, the variable squeezing of the torso creates a bellows-like effect, which pulls air into the lungs even before full expulsion from the mother. There is no experimental literature to support this proposed mechanism.

Overall, few studies have systematically examined the potential for false-positive or false-negative results. Additionally, unlike gross photographs or glass slides, the lung float test cannot be replicated or reviewed by another forensic pathologist after the original autopsy.

With this paucity of data and the variable ways in which the test can be performed, it is impossible to assess the confidence intervals and relative specificity and sensitivity of the float test. It is thus reasonable to conclude that the float test is not a test but an autopsy finding. It should therefore, along with all other findings, be interpreted in the totality of the case and is not a diagnostic tool able to stand on its own as the sole determinant of whether an infant is liveborn or stillborn.

Examination of the lungs (gross and microscopic)

Gross and microscopic findings of the lungs have been proposed to distinguish liveborn neonates from stillborn fetuses [49, 64-67]. One study examined the lung findings of 171 infants, including whether the lungs fill the thoracic cavity and cover the anterior surface of the heart, and the degree of alveolar expansion (e.g., uniform, semi-collapsed, collapsed) on microscopy. Unfortunately, the reliability of their findings is diminished by the study population being composed entirely of potential neonaticides or medical malpractice cases. Additionally, the study collected data by review of autopsy reports while using the final determination of livebirth or stillbirth from the same reports, thereby engaging in circular reasoning [67].

Further complicating the significance of lung findings is that atelectasis has been observed in the lungs of liveborn infants while expanded alveoli have been observed in the lungs of stillborn fetuses. According to some studies, the histological appearance of the alveoli is more indicative of fetal maturity than the presence of respiration. One study reported localized expansion of the air-passages in the respiratory bronchi and alveolar ducts was only found in the liveborn infants [65].

Pulmonary interstitial emphysema (PIE) has been experimentally evaluated and is considered diagnostic of live birth by some authors [64, 66, 68]. PIE is a condition where there is accumulation of gas-forming pleural blebs and pneumothoraces secondary to alveolar wall rupture and tracking of air in interlobular pulmonary vascular sheaths. It has been seen in premature infants receiving mechanical ventilation and also with resuscitation [69]. In a study of 87 infants (66 liveborn and 21 stillborn), Lavezzi *et al*. were able to demonstrate florid PIE in 16 liveborn infants – however, 12 had received cardiopulmonary resuscitation and/or mechanical ventilation. None of the stillborn fetuses showed florid PIE, but “equivocal” PIE was identified in both groups [66]. While these studies show promise for PIE as a diagnostic parameter, one report from a different institution raised concerns about the validity and reproducibility of this finding [70, 71] . PIE also may occur by artificial

respiration or putrefaction [72]. Therefore, additional studies are needed to validate PIE on a larger scale (i.e., across different institutions research groups) to ensure inter- and intra-observer reproducibility.

Postmortem Imaging

The presence of air in the lungs and/or gastrointestinal tract on postmortem radiography may be supportive of a liveborn infant. In utero, there is no air in the gastrointestinal tract. After birth, a child will breathe and swallow air which can inflate the stomach and intestines. The survey of forensic pathologists found 29% believed that postmortem plain radiology helps distinguish liveborn from stillborn infants. Computed tomography (CT) scans may also demonstrate aeration of the lungs [73, 74]. However, attempts at resuscitation in a stillborn fetus and/or decomposition may also result in this finding.

Five studies were found examining postmortem CT scans [62, 73, 75-77] which showed some utility in identifying the presence of air in the lungs and gastrointestinal tract in liveborn neonates. However, all these studies are limited by small sample size (between 4 and 12 decedents each) and the inclusion of “unknowns” (i.e., potential neonaticides) in the study population.

Barber *et al.* investigated the utility of postmortem magnetic resonance imaging (MRI) in distinguishing livebirth from stillbirth by examining the presence of air in the lungs, gastrointestinal tract, heart, and hepatobiliary system. This study included 42 decedents whose births were witnessed in hospital and therefore could be confirmed as liveborn or stillborn. They found that lung aeration was highly accurate in identifying live births although rare false negatives did occur. Resuscitation was still suspected as the source of aeration in one stillbirth. The authors recommended further validation of their findings with larger cohorts. In addition to the need for larger studies, CT and MRI are only occasionally accessible to coroners and medical examiners [74].

Trauma with associated hemorrhage

Blunt force injury with an extent of hemorrhage that would not be expected with the vaginal delivery of a stillborn fetus demonstrates an active circulation of blood at the time of the extrauterine injury. One may see a cephalohematoma or prominent caput succedaneum from vaginal delivery or pelvic-cephalic engagement, but this alone does not prove livebirth as the fetus may still have died before expulsion from the uterus. While the assessment of the degree of hemorrhage can be somewhat subjective, extreme or extensive hemorrhages in the setting of associated injuries (e.g.,skull fractures with extensive hemorrhage), may allow for a determination of live birth to be made in the proper setting.

Immunohistochemical studies

Immunochemical studies have been proposed to help distinguish liveborn neonates from stillborn fetuses. One study demonstrated different expression(s) of mast cell tryptase, the histiocytic marker CD68, and alpha-1-antichymotrypsin, suggesting that their expression(s) may be useful.. This study included 45 umbilical cord samples from documented stillborn fetuses and liveborn neonates, and found that tryptase, CD68, and alpha-1-antichymotrypsin showed a statistically significant increased expression in liveborn neonates [78]. These results are promising, but additional validation across different institutions is needed to confirm the reproducibility of the results. Immunohistochemical staining for surfactant has also shown promise as a marker for viability and lung maturity, but not as a method of differentiating livebirth from stillbirth [79]. Like postmortem imaging, access to immunohistochemistry varies among ME/C offices.

Placental findings

Findings in the placenta may offer information supportive of stillbirth. For example, evidence of a large abruption could provide a compelling etiology for an intrauterine death; however, this finding does not exclude a death occurring shortly after delivery. A large placental abruption may also help support a reported precipitous birth, contextualize the severity of an infant’s medical fragility, and may support a mother’s description of a delivery of a stillborn fetus. Other placental findings of importance include chorioamnionitis,

meconium staining (may signify fetal distress), and placental vascular disease (insufficiency). The assessment of chorionic villous maturity also has been proposed [72]. Like an abruption, all these findings may suggest either a possible etiology of a stillbirth or provide evidence that a fetus was in distress; however, they can all be found in liveborn infants as well and, therefore, are not diagnostic of stillbirth or livebirth.

Umbilical cord findings

Grossly, the umbilical cord ends may show a tear or a cut. An inflammatory reaction at the site of umbilical cord disruption has been described to support a live birth [51, 64], but the absence of this finding does not indicate stillbirth. Histologically, inflammation of the umbilical cord can be observed as early as two to three hours after birth [69]. However, in many instances, infanticide occurs just after birth before this finding can develop. Of note, tearing of the cord during delivery may cause extensive hemorrhage, which may be evident at the scene of the delivery and should be taken into consideration during the scene investigation. Inflammation of the umbilical cord may also observed in fetal deaths which occur in the setting of an intrauterine infection.

Pathologic Conditions, Fetal Malformations, Metabolic Testing, and Karyotype

Pathologic conditions that could only occur after delivery have been examined as evidence of live birth. These include aspirated food in the lungs and pulmonary hyaline membranes, as previously discussed . Hyaline membranes do not form in utero and therefore suggest livebirth and subsequent survival interval [65]. The finding of a lethal malformation or condition that precludes independent existence may help in determining if an infant was born alive. Such conditions include anencephaly, pulmonary hypoplasia, and chromosomal malformation syndromes among others. While these conditions do not preclude live birth, their presence may place the death in context as to the likelihood of extrauterine survival.

Gestational Age

Determination of the gestational age (e.g., based on fetal measurements) provides information about the viability of the fetus. Without medical intervention, extremely premature infants (i.e., <22 weeks) are generally considered unable to survive after delivery [50]. This does not necessarily speak to whether the subject was liveborn or stillborn, but may help put the death in context. Fetal ossification centers have been used as predictors of gestational age, and postmortem CT has been shown to be more reliable than autopsy examination at evaluating these [77]. Organ weights and maturation (e.g., convolutions of brain [80], histology of glomeruli) have also been used for aging.

Clinical History

In a recent survey, 94% of forensic pathologists stated that clinical history is helpful in determining livebirth or stillbirth [1]. History and circumstances provide key information to physicians including the forensic pathologist [81]. In one clinical study of 630 medical cases, history was determined the “most important” part of the diagnosis in 56%; in contrast, physical examination was “most important” in only 17% [82]. Without history, all physicians would be at a great disadvantage to make a proper diagnosis. Clinical history and scene investigation are always a cornerstone of adequate autopsy and death investigation. This does not imply, however, that the pathologist should rely completely on the statements of the mother. The reliability of the witness statements may be influenced by many factors including, but not limited to, concerns of criminal charges or prosecution, mental illness, intellectual disability or cognitive impairment, acute physical and emotional distress, and intoxication. The presence of other witnesses with consistent accounts is helpful, and video or photographic documentation may be decisive. It is important to consider whether attempts were made at resuscitation, thus potentially introducing air into the body. If available, obstetrician notes from the pregnancy should be reviewed as they may confirm the presence of conditions which increase the risk of stillbirth. The clinical history and circumstances of death are critical to informing the autopsy procedure and to appropriately contextualize the findings. Therefore, these pieces of information should be considered by the forensic pathologist when making determinations.

Conclusions and Future Studies Needed

It is relevant to note that since the Dobbs v. Jackson Supreme Court decision in 2022, there have been increasing concerns about pregnancy-related prosecutions in the United States. This places further importance on developing scientific, evidence-based, and consistent approaches to diagnosis and certification [83, 84].

Regional mandates and jurisdictional authority to investigate perinatal and fetal deaths are highly variable, and therefore blanket recommendations are inappropriate. It is reasonable to expect that deaths related to physical maternal trauma, non-natural maternal death, or when there is concern for foul play/neonaticide, are appropriate for investigation by a ME/C. Depending on jurisdiction requirements and available resources, other types of FD, stillbirth, or perinatal death can be referred to a hospital/pediatric pathologist.

The placenta should be either examined directly by the forensic pathologist or by a hospital pathologist. If the latter occurs, the forensic pathologist should review the surgical pathology report. If the placenta cannot be examined (e.g., not recovered, discarded), the pathologist should exercise caution in determining a cause of death.

Additional high-quality studies are needed to assess the validity and error rate of findings used as proof of live birth. Many of the current studies are limited by small numbers, an inappropriate study cohort (i.e., suspicious and/or unwitnessed birth and death), and a lack of validation by other groups. The best-developed evidence appears to support pulmonary interstitial emphysema, postmortem CT and MRI, and immunohistochemistry as methods to distinguish livebirth from stillbirth. While some studies support the utility of the lung float test, the failure of other studies to reproduce the same results raises serious concerns about interpreting these results in isolation. Also of concern is the inability to have this test/finding subsequently reviewed by another forensic pathologist (unlike gross photographs or glass slides).

Additional studies clarifying the mechanisms of stillbirth are crucial to public health and the field of medicine. Not only will further knowledge improve maternal and fetal health and thus prevent deaths, but it may also aid forensic pathologists in determining the underlying causes of death.

The determination of liveborn infant or stillborn fetus may have important legal consequences. Unless the evidence is clear and convincing (i.e. either stillbirth or livebirth are the only reasonable possibilities), a conclusion of “undetermined” is prudent. As “undetermined” is currently not available as an option when certifying these deaths (i.e. either a Certificate of Fetal Death or a Death Certificate is typically completed, but not both), it is recommended to default to the designation of fetal death (stillbirth) in situations with conflicting or indeterminate autopsy and investigative findings. While unattended perinatal deaths may be reported to the MEC as “suspicious,” it is important to note that the following features do not provide objective evidence of livebirth with subsequent neonaticide: concealment of pregnancy; absent prenatal care; home delivery; or maternal substance use disorder or mental illness. Therefore, while these may be reasons that deaths are reported by law enforcement or hospital staff and even investigated by ME/C, none are factual evidence of livebirth or stillbirth.

The cause and manner of death, interpreting the role of maternal SUD, and distinguishing a liveborn neonate from a stillborn fetus, are based on the autopsy and laboratory findings considered in the context of the circumstances of the death. As forensic pathology is the practice of medicine, autopsy findings should not be considered in isolation. Forensic pathologists are not required to be 100% certain about any diagnosis or expert opinion, and it is important to recognize that forensic pathologists are limited by the quality and quantity of investigative and autopsy material available, and by the extent of current scientific understanding. Ultimately, forensic pathologists should use their individual medical judgment to make a clear, scientifically sound determination.

Final Recommendations

1. Fetal deaths with a history of maternal trauma or a non-medically supervised out-of-hospital birth (e.g., a suspected fetus or neonate discovered in a garbage can) may need medicolegal investigation.

2. Medically supervised fetal deaths involving maternal drug use usually do not require medicolegal autopsy or investigation. Regional statutes may require an ME/C to accept jurisdiction when maternal drug use is suspected or confirmed, however. The detection of stimulants with a placental abruption may also result in acceptance of jurisdiction, depending on the specific circumstances and regional statutes.

> 2a. Fetal deaths and perinatal deaths in the setting of maternal SUD are the consequences of a chronic disease process which is often confounded by the presence of other risk factors for negative pregnancy outcomes. If a manner of death is required, either in the setting of live birth or in a jurisdiction which uses a modified fetal death certificate, these circumstances fit the description of a “natural” manner of death. “Accident” or “undetermined” may also be appropriate the setting of stimulants and placental abruption. If manner of death is not required on the death certificate, it is recommended the certifier not designate a manner of death in the autopsy report, case management system, or elsewhere.

3. While it may be possible to distinguish a liveborn infant from a stillborn fetus by the process of postmortem investigation, this distinction can be very difficult. All postmortem findings are interpreted in the totality of the investigation; there is no diagnostic tool or finding, aside from food in the stomach, that can stand alone as the sole determinant of whether an infant was liveborn or stillborn. The lung float procedure is of questionable value and is without clearly defined error rates. There is therefore no reason to mandate its performance. Although this procedure will still be used by some practitioners, there are known pitfalls to keep in mind and the results, as with any findings, cannot be interpreted in isolation. Those who use the lung float should be wary of accepting the results when it conforms to their summation of the findings and rejecting the result if it conflicts; a “test” used in such fashion inevitably becomes more dangerous than useful.

4. When considering a diagnosis of liveborn neonate versus a stillborn fetus, the forensic pathologist should recognize that this diagnosis may have serious legal implications. Therefore, a high degree of certainty is required to make the determination of liveborn and all other reasonable competing diagnoses should be excluded. If the autopsy and investigative findings do not provide clear and convincing evidence of live birth, .it is recommended to default to a designation of fetal death (stillbirth).

Table 1: Definitions of Live Birth, Fetal Death, and Stillbirth

Live Birth (1)	The complete expulsion or extraction from its mother of a product of human conception, irrespective of the duration of pregnancy, which, after such expulsion or extraction, breathes, or shows any other evidence of life such as beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles, whether or not the umbilical cord has been cut or the placenta is attached. Heartbeats are to be distinguished from transient cardiac contractions; respirations are to be distinguished from fleeting respiratory efforts or gasps.
Fetal death (1)	Death prior to the complete expulsion or extraction from its mother of a product of human conception, irrespective of the duration of pregnancy and which is not an induced termination of pregnancy. The death is indicated by the fact that after such expulsion or extraction, the fetus does not breathe or show any other evidence of life, such as beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles. Heartbeats are to be distinguished from transient cardiac contractions; respirations are to be distinguished from fleeting respiratory efforts or gasps.
Stillbirth, NCHS standard (1)	Fetal death of 350 grams or more, or if weight is unknown, of 20 completed weeks gestation or more, calculated from the date last normal menstrual period began to the date of delivery, which occurs in this state shall be reported within 5 days after delivery to the (Office of Vital Statistics) or as otherwise directed by the State Registrar.
Stillbirth, WHO standard (2)	The complete expulsion or extraction from a woman of a fetus, following its death prior to the complete expulsion or extraction, at 22 or more completed weeks of gestation.

Table 2:

Potential Elements of Postmortem Examination in Fetal and Early Neonatal Deaths

Postmortem radiology including plain radiographs and CT scans
Complete autopsy of the fetus/neonate
Placental examination including histology
Metabolic testing on blood and/or bile spot cards
Microbiology testing to include viral, bacterial, and fungal testing
Histology of vital organs (e.g. brain, heart, lungs, liver, kidney, spleen, thymus, thyroid gland, adrenal gland, pancreas, larynx/trachea, digestive tract, bone, umbilical cord)
Toxicological testing
Vitreous electrolyte analysis
Neuropathologic examination following formalin fixation of brain and spinal cord
Fetal karyotype

Table 3: Suggested Body Measurements for Gestational Age Estimation [15]

Weight
Foot length
Head circumference
Crown-heel length (height)
Crown-rump length
Chest circumference
Abdominal circumference
Hand length
Outer canthal distance
Inner canthal distance
Philtrum length

Table 4: Expected Anatomic findings by Gestational Age (adapted from [16])

Weeks	Skin	Hair	Eyes	Ears
16-18	Red	None	Eyelids closed, translucent	Pliable, stand out from head
18-20	Red	Eyebrows		
20-22	Red	Early scalp & lanugo	Eyelids opaque	
22-24	Red to pink	Whole body lanugo		Helix more prominent
24-26	Pink	More prominent		
26-28	Fat present	Good head of hair	Eyelids open	
30-32	Testes descending	Abundant		Spring back
36-38	Breasts protrude	Lanugo absent		Cartilage well-developed

Table 5: Sample Scenarios with Cause and Manner of Death

Scenario	**Cause of Death**	**MOD** **if required by law*
36-week gestation stillbirth; mother with pre-eclampsia, no prenatal care, and drug use during pregnancy. Placenta exam small for gestational age. Fetal meconium positive for fentanyl and cocaine,	Intrauterine fetal demise in the setting of maternal pre-eclampsia, absent prenatal care, and substance use disorder.	Natural*

39-week gestation stillbirth; mother with clinical placental abruption, confirmed by pathological examination of the placenta. Maternal use of tobacco and cocaine during pregnancy. No prenatal care. Umbilical cord blood positive for cocaine and BE.	Intrauterine fetal demise with placental abruption in the setting of maternal substance use disorder (tobacco and cocaine) and absent prenatal care.	Undetermined or Accidental*
24-week gestation live birth, died after several days in the NICU with respiratory hyaline membranes. Spontaneous preterm, premature labor with precipitous delivery. Maternal use of cocaine and opioids during pregnancy; single prenatal visit	Complications of prematurity due to spontaneous preterm, premature delivery in the setting of incomplete prenatal care and maternal substance use disorder.	Natural
25-week gestation live birth, died after several days in the NICU. Delivered by emergent c-section in the setting of fatal maternal overdose (cocaine and fentanyl).	Complications of prematurity due to emergent delivery in the setting of fatal maternal intoxication by cocaine and fentanyl.	Accident

Figure 1: The U.S. Standard Certificate of Fetal Death

References:

1. Krywanczyk A, Jackson NR, Maloney K, Gill JR. *A Survey of Forensic Pathologists Regarding Medicolegal Investigation of Perinatal and Stillborn Deaths*. Am J Forensic Med Pathol. 2025 Jun 1;46(2):122-127.
2. U.S. Centers for Disease Control and Prevention. *Data and Statistics on Stillbirth*. 2024. Available at: https://www.cdc.gov/stillbirth/data-research/index.html
3. United Nations Department of Economic and Social Affairs. *Handbook on Civil Registration and Vital Statistics Systems: Management, Operation, and Maintenance. Revision 1*. 2021.
4. Gregory, E.C.W. and W.D. Barfield, *U.S. stillbirth surveillance: The national fetal death file and other data sources*. Semin Perinatol, 2024. **48**(1): p. 151873.
5. Organization, W.H., *Constitution of the World Health Organization*. 2005.
6. J., K., *State definitions and reporting requirements for live births, fetal deaths, and induced terminations of pregnancy*. National Center for Health Statistics: Hyattsville, MD.
7. Gynecologists, A.C.o.O.a., *Obstetric Care Consensus Number 10: Management of Stillbirth*. . 2020.
8. Statistics, N.C.f.H., *Revisions of the US Standard Cerificates and Reports*.
9. Statistics, N.C.f.H. *Fetal Death Edit Specifications for the 2003 Revision of the U.S. Standard Report of Fetal Death*. 2021.
10. Parks, G. *California Department of Public Health: Process improvements could help reduce delays in completing fetal death registration*.
11. Missaghian, R., *Rhode Island Department of Health: Instructions to complete a fetal death form for under 20 weeks gestational age*.

12. Genest, D.R., *Estimating the time of death in stillborn fetuses: II. Histologic evaluation of the placenta; a study of 71 stillborns.* Obstet Gynecol, 1992. **80**(4): p. 585-92.
13. Genest, D.R. and D.B. Singer, *Estimating the time of death in stillborn fetuses: III. External fetal examination; a study of 86 stillborns.* Obstet Gynecol, 1992. **80**(4): p. 593-600.
14. Genest, D.R., M.A. Williams, and M.F. Greene, *Estimating the time of death in stillborn fetuses: I. Histologic evaluation of fetal organs; an autopsy study of 150 stillborns.* Obstet Gynecol, 1992. **80**(4): p. 575-84.
15. Archie, J.G., J.S. Collins, and R.R. Lebel, *Quantitative standards for fetal and neonatal autopsy.* Am J Clin Pathol, 2006. **126**(2): p. 256-65.
16. Ballard, J.L., K.K. Novak, and M. Driver, *A simplified score for assessment of fetal maturation of newly born infants.* J Pediatr, 1979. **95**(5 Pt 1): p. 769-74.
17. Miller, E.S., et al., *Stillbirth evaluation: a stepwise assessment of placental pathology and autopsy.* Am J Obstet Gynecol, 2016. **214**(1): p. 115 e1-6.
18. Sandoval, A. and D. Winston, *A Survey of Fetal Deaths as Reported to a Medical Examiner's Office.* Am J Forensic Med Pathol, 2022. **43**(2): p. 153-156.
19. Wilkinson Z, W.K., Gilson T, Krywanczyk A., *Intrauterine and neonatal deaths: The 2013-2023 experience of the Cuyahoga County Medical Examiner's Office.* American Journal of Forensic Medicine and Pathology, 2025. **Accepted, pending publication**.
20. Bada, H.S., et al., *Gestational cocaine exposure and intrauterine growth: maternal lifestyle study.* Obstet Gynecol, 2002. **100**(5 Pt 1): p. 916-24.
21. Kennare, R., A. Heard, and A. Chan, *Substance use during pregnancy: risk factors and obstetric and perinatal outcomes in South Australia.* Aust N Z J Obstet Gynaecol, 2005. **45**(3): p. 220-5.
22. McDonald, S.D., M.J. Vermeulen, and J.G. Ray, *Risk of fetal death associated with maternal drug dependence and placental abruption: a population-based study.* J Obstet Gynaecol Can, 2007. **29**(7): p. 556-559.
23. Odendaal, H.J., et al., *Combined effects of cigarette smoking and alcohol consumption on perinatal outcome.* Gynecol Obstet Invest, 2009. **67**(1): p. 1-8.
24. Varner, M.W., et al., *Association between stillbirth and illicit drug use and smoking during pregnancy.* Obstet Gynecol, 2014. **123**(1): p. 113-125.
25. Viteri, O.A., et al., *Relationship between Self-Reported Maternal Substance Abuse and Adverse Outcomes in the Premature Newborn.* Am J Perinatol, 2016. **33**(2): p. 165-71.
26. Stein, J.A., M.C. Lu, and L. Gelberg, *Severity of homelessness and adverse birth outcomes.* Health Psychol, 2000. **19**(6): p. 524-34.
27. Salow, A.D., et al., *Associations of neighborhood-level racial residential segregation with adverse pregnancy outcomes.* Am J Obstet Gynecol, 2018. **218**(3): p. 351 e1-351 e7.
28. Lee, H., et al., *Different levels of associations between medical co-morbidities and preterm birth outcomes among racial/ethnic women enrolled in Medicaid 2014-2015: retrospective analysis.* BMC Pregnancy Childbirth, 2020. **20**(1): p. 33.
29. Liu, B., et al., *Maternal cigarette smoking before and during pregnancy and the risk of preterm birth: A dose-response analysis of 25 million mother-infant pairs.* PLoS Med, 2020. **17**(8): p. e1003158.
30. Adams, A., et al., *Social Determinants of Health and Risk of Stillbirth in the United States.* Am J Perinatol, 2024. **41**(S 01): p. e477-e485.
31. Gilmore, E., K. Duncan, and V. Ades, *Homelessness in Pregnancy and Increased Risk of Adverse Outcomes: A Retrospective Cohort Study.* J Urban Health, 2024. **101**(2): p. 383-391.
32. Finnegan, L.P., D.S. Reeser, and J.F. Connaughton, Jr., *The effects of maternal drug dependence on neonatal mortality.* Drug Alcohol Depend, 1977. **2**(2): p. 131-40.
33. El-Mohandes, A., et al., *Prenatal care reduces the impact of illicit drug use on perinatal outcomes.* J Perinatol, 2003. **23**(5): p. 354-60.
34. Hopson, D.L. and J. Ross, *Maternal Abortifacient use for Clandestine Abortion.* Acad Forensic Pathol, 2016. **6**(4): p. 663-672.
35. Szpot, P., O. Wachelko, and M. Zawadzki, *Forensic Toxicological Aspects of Misoprostol Use in Pharmacological Abortions.* Molecules, 2022. **27**(19).

36. Butler, D.C., et al., *Microcrystalline Cellulose and Crospovidone Identified in Placentas With Vaginal Misoprostol Use.* Am J Forensic Med Pathol, 2020. **41**(3): p. 176-181.
37. Miller, C.B. and T. Wright, *Investigating Mechanisms of Stillbirth in the Setting of Prenatal Substance Use.* Acad Forensic Pathol, 2018. **8**(4): p. 865-873.
38. Ortigosa, S., et al., *Feto-placental morphological effects of prenatal exposure to drugs of abuse.* Reprod Toxicol, 2012. **34**(1): p. 73-9.
39. Borrelli, K.N., et al., *Effect of Prenatal Opioid Exposure on the Human Placental Methylome.* Biomedicines, 2022. **10**(5).
40. Carter, R.C., et al., *Alcohol, Methamphetamine, and Marijuana Exposure Have Distinct Effects on the Human Placenta.* Alcohol Clin Exp Res, 2016. **40**(4): p. 753-64.
41. Hoskins, I.A., et al., *Relationship between antepartum cocaine abuse, abnormal umbilical artery Doppler velocimetry, and placental abruption.* Obstet Gynecol, 1991. **78**(2): p. 279-82.
42. Slutsker, L., *Risks associated with cocaine use during pregnancy.* Obstet Gynecol, 1992. **79**(5 (Pt 1)): p. 778-89.
43. Addis, A., et al., *Fetal effects of cocaine: an updated meta-analysis.* Reprod Toxicol, 2001. **15**(4): p. 341-69.
44. Flowers, D., J.F. Clark, and L.S. Westney, *Cocaine intoxication associated with abruptio placentae.* J Natl Med Assoc, 1991. **83**(3): p. 230-2.
45. Brandt, J.S. and C.V. Ananth, *Placental abruption at near-term and term gestations: pathophysiology, epidemiology, diagnosis, and management.* Am J Obstet Gynecol, 2023. **228**(5S): p. S1313-S1329.
46. Shah, R., et al., *Prenatal methamphetamine exposure and short-term maternal and infant medical outcomes.* Am J Perinatol, 2012. **29**(5): p. 391-400.
47. Hanzlick R, H.J., Davis GJ, *A guide for manner of death classification.* . 2002, National Association of Medical Examiners: Atlanta, GA.
48. Davis, G.G., et al., *Position Paper: Recommendations for the Investigation, Diagnosis, and Certification of Deaths Related to Opioid and Other Drugs.* Am J Forensic Med Pathol, 2020. **41**(3): p. 152-159.
49. Cohen, M.C. and I. Scheimberg, *Forensic Aspects of Perinatal Deaths.* Acad Forensic Pathol, 2018. **8**(3): p. 452-491.
50. Phillips, B. and B.B. Ong, *"Was the Infant Born Alive?" A Review of Postmortem Techniques Used to Determine Live Birth In Cases of Suspected Neonaticide.* Acad Forensic Pathol, 2018. **8**(4): p. 874-893.
51. Ong, B.B. and M. Green, *Infanticide in Malaysia: two case reports and a review of literature.* Am J Forensic Med Pathol, 2003. **24**(1): p. 64-9.
52. Shanklin, D.R., D.A. Climino, and T.H. Lamb, *Fetal Maceration. 1. An Experimental Sequence in the Rabbit.* Am J Obstet Gynecol, 1964. **88**: p. 213-23.
53. Shanklin, D.R., *Fetal Maceration. 2. An Analysis of 53 Human Stillborn Infants.* Am J Obstet Gynecol, 1964. **88**: p. 224-9.
54. Gold, K.J., et al., *Assessment of "fresh" versus "macerated" as accurate markers of time since intrauterine fetal demise in low-income countries.* Int J Gynaecol Obstet, 2014. **125**(3): p. 223-7.
55. Alfsen, G.C., C.L. Ellingsen, and L. Hernaes, *<<The child has lived and breathed.>> Forensic examinations of newborns 1910-1912.* Tidsskr Nor Laegeforen, 2013. **133**(23-24): p. 2498-501.
56. Arrowsmith, R., *On the Hydrostatic Test, and Other Proofs of the Extra-Uterine Life of the Child.* Lond Med Phys J, 1829. **7**(41): p. 412-424.
57. Brittain, R.P., *The Hydrostatic and Similar Tests of Live Birth: A Historical Review.* Med Leg J, 1963. **31**: p. 189-94.
58. Grosse Ostendorf, A.L., et al., *Is the lung floating test a valuable tool or obsolete? A prospective autopsy study.* Int J Legal Med, 2013. **127**(2): p. 447-51.
59. Moar, J.J., *The hydrostatic test--a valid method of determining live birth?* Am J Forensic Med Pathol, 1997. **18**(1): p. 109-10.
60. C, M., *Neonatal deaths, infanticide, and the hydrostatic (floatation) test: Historical perspectives.* Acad Forensic Pathol, 2012. **2**(4): p. 338-345.
61. Kellett, R.J., *Infanticide and child destruction--the historical, legal and pathological aspects.* Forensic Sci Int, 1992. **53**(1): p. 1-28.

62. Mazuchowski, E.L., et al., *The Virtual Hydrostatic Test.* Am J Forensic Med Pathol, 2017. **38**(1): p. 24-28.
63. Ahmed A, A.D., *The faulty science of the floating lung test: more pseudo forensic science.* , in *National Association of Criminal Defense Lawyers. The Champion.* 2020. p. 46-63.
64. Lavezzi, W.A., et al., *The use of pulmonary interstitial emphysema as an indicator of live birth.* Am J Forensic Med Pathol, 2003. **24**(1): p. 87-91.
65. Kuroda, S., et al., *Medico-Legal Studies on the Fetus and Infant: With Special References to Histological Characteristics of the Lungs of Liveborn and Stillborn Infants.* Tohoku J Exp Med, 1965. **85**: p. 40-54.
66. Lavezzi, W.A., B.J. McKenna, and B.C. Wolf, *The significance of pulmonary interstitial emphysema in live birth determination.* J Forensic Sci, 2004. **49**(3): p. 546-52.
67. Turan N, P.I., Yilmaz R, Gunce E, *Validity of pathologic comment with macroscopic and microscopic findings of infant lung regarding live or still birth.* . Journal of Forensic Research, 2011. **2012**: p. 1-5.
68. deRoux, S.J. and N.C. Prendergast, *Pulmonary interstitial emphysema in live birth determination: radiographic and gross pathologic features.* J Forensic Sci, 2006. **51**(1): p. 134-6.
69. W, J., *Forensic Histopathology*. 1984, Germany: Springer-Verlag Berlin.
70. Whaley, K.D., *A caveat concerning unequal aeration and pulmonary interstitial emphysema in fetal lungs.* Am J Forensic Med Pathol, 2006. **27**(2): p. 196.
71. Wolf, B.C. and W.A. Lavezzi, *Pulmonary interstitial emphysema and live birth.* Am J Forensic Med Pathol, 2008. **29**(4): p. 382.
72. Marchetti, D., et al., *Evaluation of the placenta in a stillborn fetus to estimate the time of death.* Am J Forensic Med Pathol, 2007. **28**(1): p. 38-43.
73. Guddat, S.S., et al., *Proof of live birth using postmortem multislice computed tomography (pmMSCT) in cases of suspected neonaticide: advantages of diagnostic imaging compared to conventional autopsy.* Forensic Sci Med Pathol, 2013. **9**(1): p. 3-12.
74. Barber, J.L., et al., *Lung aeration on post-mortem magnetic resonance imaging is a useful marker of live birth versus stillbirth.* Int J Legal Med, 2015. **129**(3): p. 531-6.
75. Ducloyer, M., et al., *Lung density measurement in postmortem computed tomography: a new tool to assess immediate neonatal breath in suspected neonaticides.* Int J Legal Med, 2020. **134**(3): p. 1159-1166.
76. Michiue, T., et al., *Postmortem CT investigation of air/gas distribution in the lungs and gastrointestinal tracts of newborn infants: a serial case study with regard to still- and live birth.* Forensic Sci Int, 2013. **226**(1-3): p. 74-80.
77. Sieswerda-Hoogendoorn, T., et al., *The value of post-mortem CT in neonaticide in case of severe decomposition: description of 12 cases.* Forensic Sci Int, 2013. **233**(1-3): p. 298-303.
78. Neri, M., et al., *Stillborn or liveborn? Comparing umbilical cord immunohistochemical expression of vitality markers (tryptase, alpha(1)-antichymotrypsin and CD68) by quantitative analysis and confocal laser scanning microscopy.* Pathol Res Pract, 2009. **205**(8): p. 534-41.
79. Zhu, B.L., et al., *Immunohistochemical investigation of pulmonary surfactant in perinatal fatalities.* Forensic Sci Int, 1996. **83**(3): p. 219-27.
80. Dorovini-Zis, K. and C.L. Dolman, *Gestational development of brain.* Arch Pathol Lab Med, 1977. **101**(4): p. 192-5.
81. Leadbeatter, S. and B. Knight, *The history and the cause of death.* Med Sci Law, 1987. **27**(2): p. 132-5.
82. Sandler, G., *The importance of the history in the medical clinic and the cost of unnecessary tests.* Am Heart J, 1980. **100**(6 Pt 1): p. 928-31.
83. Reingold, R.B., L.O. Gostin, and M.B. Goodwin, *Legal Risks and Ethical Dilemmas for Clinicians in the Aftermath of Dobbs.* JAMA, 2022. **328**(17): p. 1695-1696.
84. Delliger J, P.S., *Bodies of Evidence: The Criminalization of Abortion and Surveillance of Women in a Post-Dobbs World.* Duke Journal of Constitutional Law and Public Policy, 2024. **19**: p. 1-108.