Estimating the Time of Death in Stillborn Fetuses: III. External Fetal Examination; a Study of 86 Stillborns

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Objective: **To determine how accurately the time of fetal death can be predicted from the extent of external maceration in a stillborn fetus.**

Methods: **Autopsy photographs of 86 stillborns with well-timed deaths were studied retrospectively. Sixty randomly chosen fetuses (learning set) were assessed unblinded to develop proposed gross criteria for timing fetal death; 26 fetuses (test set) were then randomly and blindly assessed to test the accuracy of the proposed criteria.**

Results: **The two earliest changes in the learning cases were areas of desquamation measuring at least 1 cm in diameter and brown-red discoloration of the umbilical cord stump. Both changes occurred primarily in fetuses with death-to-delivery intervals of 6 or more hours. Other early changes included desquamation involving the face, abdomen, or back (12 or more hours); desquamation involving 5% or more of the body surface (18 or more hours); brown skin discoloration (24 or more hours); and a moderate or severe extent of desquamation (24 or more hours). The only late change that correlated with a specific duration of intrauterine retention was mummification (2 or more weeks). When the 26 test fetuses were randomly and blindly assessed using these gross criteria, 18 (69%) were classified correctly with respect to the approximate time of fetal death.**

Conclusion: **External fetal examination is useful for estimating the time of death in many stillborns; this information may be helpful when a complete autopsy cannot be performed.** ***(Obstet Gynecol 1992;80:593–600)***

Fetal death is an important obstetric problem, accounting for approximately half of perinatal deaths.[1] When detailed pathologic assessment of the stillborn fetus and its placenta are performed, a probable cause for fetal death can be established in most cases.[2] In some instances, however, the parents of a stillborn fetus do not grant permission for a fetal autopsy. In these cases it would be desirable if the parents would allow a pathologist, obstetrician, pediatrician, or dysmorphologist to perform a careful external examination of the fetus, supplemented by gross photographs and radiographs. This procedure might be useful in two ways: 1) It would allow documentation of fetal development and external congenital anomalies (information relevant in planning future pregnancies); and 2) it might permit estimation of the time of fetal death (information that could help to explain the death). Although the literature amply supports the first of these points,[3] the reliability of external fetal examination for determining the time of intrauterine death has not been studied systematically. We conducted this study to determine whether the timing of intrauterine death may be determined from external examination of a stillborn fetus.

Materials and Methods

We reviewed the medical records of women who delivered stillborn fetuses at the Brigham and Women's Hospital over the period 1980–1991. Eighty-six stillborns were identified for which the timing of fetal death was accurately determined by clinical studies (serial ultrasound or Doppler examinations) and for which autopsy color photographs of good quality were available for review. These 86 fetuses represented 57% of the 150 stillborn fetuses previously described in our paper dealing with autopsy histology (this issue, page 575). The following data were obtained for each case: 1) birth-to-autopsy interval, 2) gestational age at the time of death, 3) clinical-pathologic evidence of acute or chronic fetal stress (fetal growth retardation, maternal preeclampsia, abruptio placentae, prolapsed cord, numerous petechiae, or diffuse hemorrhage at autopsy),

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4) presence of amniotic or fetal infection (acute chorioamnionitis, positive autopsy cultures, or organisms on microscopic examination of fetal tissues), and 5) presence of fetal hydrops.

The autopsy photographs, retrieved from the pathology files, were projectable color transparencies taken by the pathologist before autopsy. In all cases, a well-focused, whole-body anteroposterior view was available. In addition, 83% of cases had whole-body lateral views and 21% had one or more close-up views. Centimeter rulers had been photographed adjacent to all fetuses. Photographs depicting internal features were not assessed, nor were the pathologist's descriptions of the internal findings.

Before reviewing the photographs of the 86 cases, we randomly divided the cases into a "learning set" of 60 cases and a "test set" of 26 cases. The first phase of the study focused on the learning cases.

Initially, all photographs were reviewed simultaneously by both authors (perinatal pathologists) in an unblinded fashion; cases were arranged in temporal sequence (starting with fetuses with the shortest death-to-delivery intervals). Table 1 presents the gross features assessed in each fetus. Desquamation was defined as an area where the epidermis was missing, exposing the underlying dermis. When evaluating skin color, the background pigmentation in areas of "normal" skin was compared with regions of "discolored" skin. Mummification was identified when fetal tissues had a dehydrated appearance; this was always associated with a tan-brown skin color and was often associated with compression or flattening of the fetus.

After evaluating the photographs, we assessed each gross characteristic individually as a possible diagnostic test for the following death-to-delivery intervals: less than 2 hours, 2 or more hours, 4 or more hours, 6 or more hours, 8 or more hours, 12 or more hours, 18 or more hours, 24 or more hours, 36 or more hours, 48 or more hours, 72 or more hours, 96 or more hours, 1 or more weeks, 2 or more weeks, 3 or more weeks, 4 or more weeks, and 8 or more weeks. Each feature was assessed in terms of sensitivity, specificity, and positive predictive values for each death-to-delivery interval. Only the gross features that performed optimally for a specific death-to-delivery interval (sensitivity, specificity, and positive predictive value at or above 0.800) were subsequently used to evaluate the 26 test fetuses. Gross features were also evaluated for possible associations with factors other than the timing of fetal death, including gestational age, infection, fetal stress, delivery-to-autopsy interval, and hydrops.

Initially, the 26 test fetuses were simultaneously analyzed by both investigators in a randomized fashion. The investigators were blinded to the death-to-delivery intervals and all other clinical and pathologic information. Assessment was limited to those gross features that performed optimally in the learning set (sensitivity, specificity, and positive predictive values all at or above 0.800). After assessing the photographs of all test fetuses, we performed two types of analysis. First, each gross feature was assessed individually as a diagnostic test for its predicted intrauterine retention

Table 1. Gross Features Assessed in the 60 Learning Cases

Feature	Categorization of feature
Skin color	1) Normal/pink 2) Partially red 3) Totally red 4) At least partially brown 5) At least partially tan
Cord color	1) Normal 2) Brown 3) Brown-red
Mouth	1) Closed 2) Partly open 3) Widely open
Lip color	1) Normal 2) Abnormal (red/brown)
Eyelid color	1) Normal 2) Abnormal (dark red)
Cranium	1) Not collapsed 2) Partially collapsed 3) Severely collapsed
Desquamation	
a) Extent	1) None 2) Slight degree 3) Moderate degree 4) Severe degree
b) Surface area involved	1) <5% 2) 5–10% 3) 10–25% 4) 25–50% 5) 50–75% 6) >75%
c) Diameter (cm) of largest area of exposed dermis	
d) Regions of body affected	1) Scalp 2) Face 3) Neck 4) Chest 5) Abdomen 6) Back 7) Arm 8) Hand 9) Leg 10) Foot 11) Scrotum
Mummification	1) None 2) Regional 3) Diffuse

time (in terms of sensitivity, specificity, and positive predictive value). Next, the findings in each fetus were assessed collectively to determine whether the collection of gross characteristics could accurately determine the time of intrauterine death. The most advanced gross finding was used to predict the time of fetal death.

To determine the reproducibility of this method of gross fetal evaluation, each observer independently reevaluated 40 randomly selected cases. Inter- and intra-observer agreement values and kappa values[4] were calculated.

Results

Among the 86 stillborn fetuses studied, the average gestational age at the time of fetal death was 27.5 weeks (range 18–41); gestational ages were similar in the learning set (average 27.9 weeks, range 18–41) and the test set (average 26.6 weeks, range 20–38). The mean birth weight was 1098.3 g (range 85–3350) for all cases, 1186.8 g (range 124–3350) in the learning set, and 894 g (range 85–3170) in the test set. The median intrauterine retention time following death was 19.5 hours (range 0.3–3528) in all cases, 26.0 hours (range 0.3–3528) in the learning cases, and 15.0 hours (range 0.5–1728) in the test cases. The time from death until birth was less than 6 hours for 32% of the learning cases and 42% of the test cases, 6–48 hours for 28% of learning cases and 30% of test cases, and more than 48 hours for 40% of learning cases and 28% of test cases.

Eight gross features correlated reasonably well with specific death-to-delivery times in terms of sensitivity, specificity, and positive predictive values of 0.800 or more (Table 2). Among these features, the earliest changes noted were areas of desquamated skin measuring 1 cm or more in diameter, and brown or red discoloration of the umbilical cord stump. Both of these changes correlated with fetal death 6 or more hours before birth. Other early changes that appeared to correlate well with specific death-to-delivery intervals included: desquamation involving the skin of the face, back, or abdomen (12 or more hours), desquamation of 5% or more of the body surface (18 or more hours), and desquamation involving two or more regions of the body (18 or more hours). When fetal death preceded birth by 24 or more hours, two additional findings were frequently present: brown or tan discoloration of the skin, usually involving the abdomen; and a moderate or severe extent of desquamation. The only gross feature that appeared to be associated with a prolonged period of intrauterine retention was mummification of part or all of the fetus; this was seen in fetuses who had died 2 or more weeks before birth.

Table 2. Performance of Gross Findings as Indicators of Intrauterine Retention Time: 60 Learning Cases

Gross finding	Retention time	Sensitivity	Specificity	Positive predictive value
Good predictors				
Desquamation ≥1 cm	≥6 h	0.853	0.812	0.921
Cord discoloration (brown or red)	≥6 h	0.947	0.867	0.947
Desquamation face, back, or abdomen	≥12 h	0.864	0.905	0.941
Desquamation ≥5% of body	≥18 h	0.862	0.920	0.926
Desquamation 2 or more of 11 zones*	≥18 h	0.931	0.920	0.931
Skin color brown or tan	≥24 h	0.828	0.928	0.923
Moderate or severe desquamation	≥24 h	0.896	0.857	0.867
Mummification (any)	≥2 wk	0.888	1.000	1.000
Intermediate predictors				
Any desquamation	≥3 h	0.878	0.667	0.923
Skin color tan	≥4 wk	1.000	0.962	0.714
Poor predictors				
Any cranial compression	≥36 h	0.619	0.935	0.866
Desquamation: >10% of body	≥48 h	0.904	0.857	0.791
Desquamation: >75% of body	≥72 h	0.529	0.945	0.818
Widely opened mouth	≥1 wk	0.700	0.837	0.500

* Scalp, face, neck, chest, abdomen, back, arms, hand, leg, foot, and scrotum.

Two additional gross findings were rated as intermediate predictors and four findings were rated as poor predictors (Table 2); these findings did not per-

Table 3. Performance of Gross Findings as Indicators of Intrauterine Retention Time: 26 Test Cases

Gross finding	Retention time	Sensitivity	Specificity	Positive predictive value
Good predictors				
Desquamation ≥1 cm	≥6 h	0.857	1.000	1.000
Desquamation face, back, or abdomen	≥12 h	0.800	1.000	1.000
Desquamation ≥5% of body	≥18 h	0.800	1.000	1.000
Desquamation 2 or more of 11 zones*	≥18 h	0.900	0.923	0.900
Mummification (any)	≥2 wk	1.000	1.000	1.000
Intermediate-poor predictors				
Cord discoloration (brown or red)	≥6 h	0.833	0.667	0.768
Skin color brown or tan	≥24 h	0.800	0.800	0.727
Moderate or severe desquamation	≥24 h	0.700	0.933	0.875

* Scalp, face, neck, chest, abdomen, back, arms, hand, leg, foot, and scrotum.

Table 4. Classification of Test Fetuses for Intrauterine Retention Interval

Correctly classified cases (N = 18)				Incorrectly classified cases (N = 8)		
Predicted time (h)	Actual time (h)	Predicted time (h)	Actual time (h)	Predicted time (h)	Actual time (h)	Incorrect prediction
0–6	0–1	24–336	28–39	24–336	0–2	Skin brown*
0–6	0–1	24–336	39–43	6–12	0–2	Cord red-brown†
0–6	0–2	24–336	60–96	6–12	0–2	Cord red-brown‡
0–6	0–2	24–336	79–151	24–336	0–6	Skin brown§
0–6	0–4	24–336	96–192	6–12	4	Cord red-brown‖
0–6	0–6	24–336	192–288	18–24	5–16	Desquamation of 2 or more zones¶
6–12	6–10	24–336	228–456	24–336	8–24	Moderate/severe desquamation#
18–24	9–21	>336	528–1344	24–336	15–22	Skin brown and moderate/severe desquamation**
24–336	27–31	>336	1440–2016			

* Group B streptococcal sepsis (22 wk); birth-to-autopsy time 48 h.
† Placental abruption (20 wk); birth-to-autopsy time 9 h.
‡ Premature rupture of membranes (26 wk); birth-to-autopsy time 24 h.
§ Premature rupture of membranes (21 wk); birth-to-autopsy time 38 h.
‖ Prolapsed cord (24 wk); birth-to-autopsy time 160 h.
¶ Placental abruption (23 wk); birth-to-autopsy time 9 h.
# Idiopathic nonimmune hydrops (30 wk); birth-to-autopsy time 39 h.
** *Escherichia coli* sepsis (31 wk); birth-to-autopsy time 20 h.

form as well as the good predictors in terms of sensitivity, specificity, and positive predictive value. Only the eight good predictors were used to assess the test set.

The eight good predictors were evaluated for possible associations with the following variables: gestational age at the time of fetal death (less than or greater than 28 weeks), hydrops, fetal infection, birth-to-autopsy interval more than 24 hours, and fetal acute/chronic stress. The median death-to-delivery intervals associated with the eight gross changes were not influenced consistently by gestational age, birth-to-autopsy interval, infection, or fetal stress. The presence of hydrops appeared to accelerate maceration in that hydrops was associated with shorter median death-to-delivery intervals for each of the eight gross features (data not shown; available upon request).

When the eight good predictors were individually assessed in the 26 test cases, five features performed well as predictors of specific intrauterine retention times (sensitivity, specificity, and positive predictive values at or above 0.800); three features did not perform as well for predicting the intrauterine retention time (any value below 0.800) (Table 3).

Next, the gross features found in each fetus were analyzed collectively to determine the ability of the set of gross findings to predict correctly the length of intrauterine retention. The most advanced gross feature was used to predict the timing of fetal death. Eighteen of 26 cases (69%) were correctly assigned to one of six intrauterine retention intervals (0–6, 6–12, 12–18, and 18–24 hours; 24–336 hours [2 weeks]; and 2 or more weeks). Eight cases (31%) were misclassified (Table 4), seven of which had been misclassified based upon a single false-positive result (ie, one gross feature was incorrect [false-positive] while seven gross features were correct). The most frequently incorrect gross features were umbilical cord discoloration (in fetuses dead less than 6 hours [three cases]) and brown skin discoloration (in fetuses dead less than 24 hours [two cases]). Because these single false-positive results were responsible for most incorrect predictions, we reassessed all cases using the following modifications of the original method: 1) If a single gross change was present, this change was discounted; and 2) if two or more gross changes were present, all changes were counted. Using this modification, 22 of 26 cases (85%) were classified correctly with respect to the duration of intrauterine fetal retention. Using this modification, each of the discounted gross variables involved discoloration of the skin or umbilical cord.

Figures 1–5 illustrate the gross findings in five representative fetuses. To test the reproducibility of the proposed method of gross fetal assessment, 40 randomly selected cases were reassessed independently by the two observers. For observer A, intra-observer agreement ranged from 84% (brown skin discoloration) to 100% (desquamation more than 1 cm in diameter), and kappa values[4] ranged from 0.633–1.00. For observer B, intra-observer agreement ranged from 81% (brown skin discoloration) to 97% (desquamation more than 1 cm in diameter), and kappa values ranged from 0.593–0.972. When inter-observer variability was as-

sessed, agreement rates ranged from 76–100%, and kappa values[4] ranged from 0.493–1.00.

Discussion

Numerous descriptions of the gross external features of maceration in stillborn fetuses have appeared in the perinatal pathologic literature.[5–13] One of the earliest detailed descriptions of maceration, that of Strachan in 1922,[5] was based upon observations of 22 stillborn fetuses. According to Strachan, the disappearance of vernix caseosa is the "first change," followed "later on" by the beginning of skin peeling. "In the more advanced cases," the skin is eroded in patches. Finally, "only in the most advanced cases," desquamation involves the scalp. Although these changes were described as a sequential process, Strachan did not specify death-to-delivery times for the development of individual changes. Most subsequent discussions of fetal maceration describe a step-like, sequential process correlated (to some degree) with the length of intrauterine retention following fetal death.[6–13] Several authors[6–8] have included an approximate "time frame" for the development of specific "stages" of maceration. Langley[6] noted that the skin begins to peel approximately 8 hours after fetal death; Bain[7] described extensive skin peeling as characteristic of at least 48 hours of intrauterine retention; and Potter and Craig[8] described the development of olive-brown skin coloration beginning 1 week after death. In all publications to date, the sequence of gross changes appears to be based upon the authors' empirical observations or the previously published descriptions of maceration. No study has described the methods used to investigate maceration or the clinical methods used to document the time of fetal death. Thus, it is not clear whether previous authors calculated the time of fetal death from maternal recall of absent fetal movement, observation of an

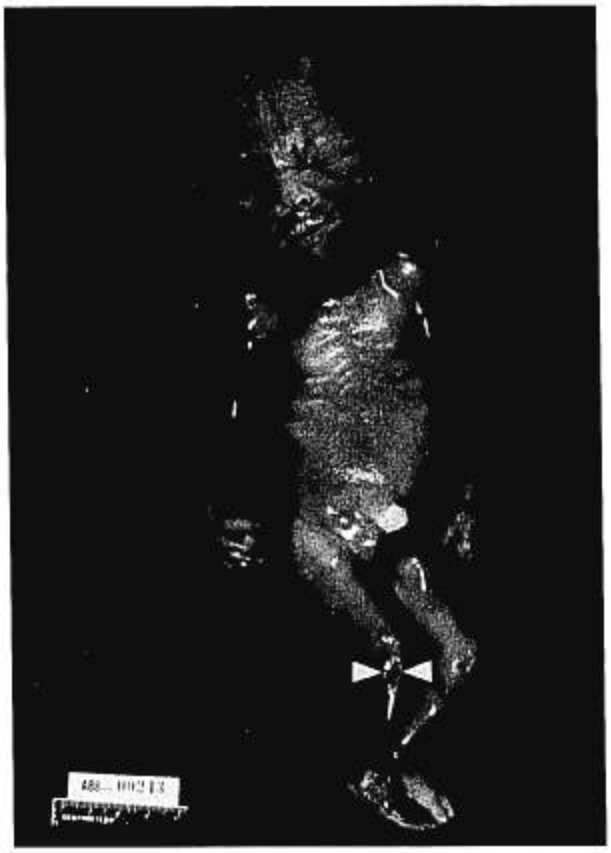

Figure 1. 22-week fetus (480 g) who died intrapartum less than 9 hours before birth. The color of the umbilical cord is normal; although slight desquamation is present (*arrows*), it is limited to the right leg and measures less than 1 cm in diameter. These findings suggest fetal death less than 6 hours before birth.

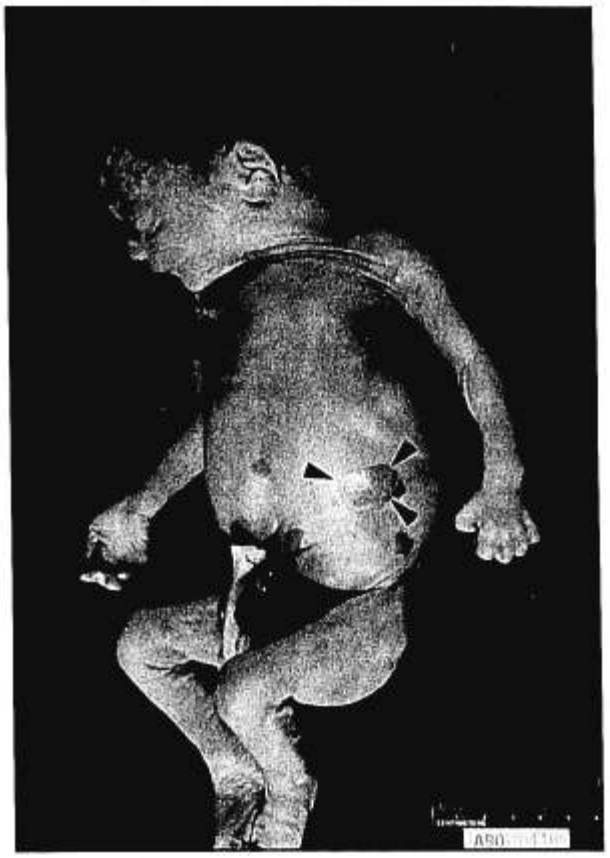

Figure 2. 27-week fetus (760 g) who died between 10–14 hours before birth. Note umbilical cord discoloration and 3-cm area of desquamation involving the abdomen (*arrows*). These features are consistent with approximately 12–18 hours of intrauterine retention after death.

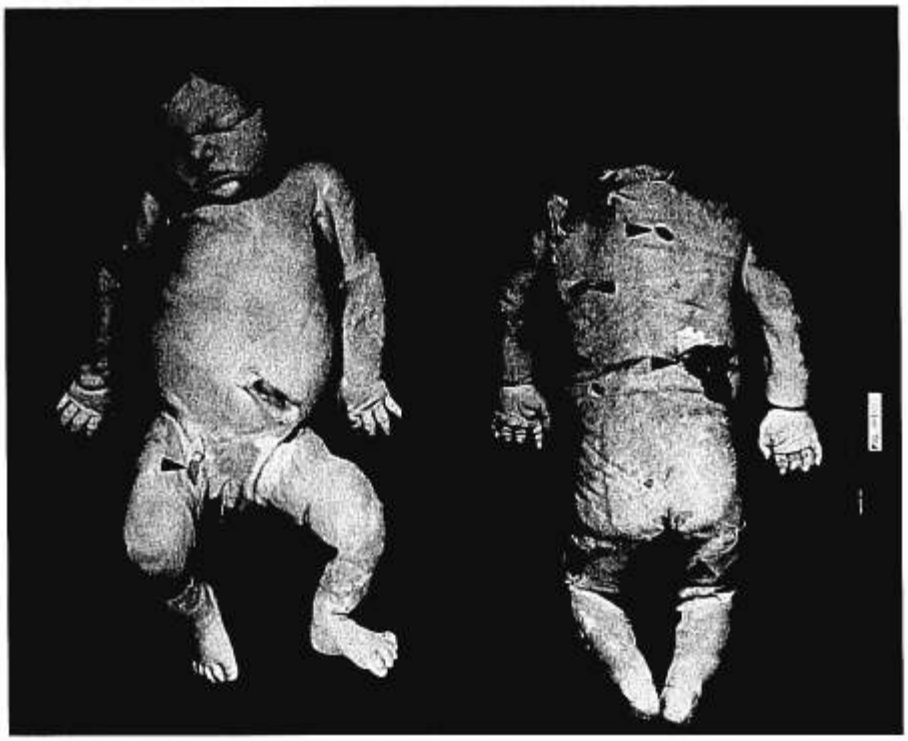

Figure 3. Anterior and posterior views of a 36-week fetus (3170 g) who died between 9–21 hours before birth. Note the umbilical cord discoloration. Desquamation involves at least two regions (leg and back) (*arrows*) and at least 5% of the body surface. These features suggest approximately 18–24 hours of postmortem retention.

absent heartbeat by the obstetrician, or confirmation of fetal death by the ultrasonographer.

Because all previous descriptions of fetal maceration appear to be based upon empirical rather than experimental observations, the ability to determine the approximate time of fetal death from the gross changes of maceration is unknown. Despite this, Becker and Becker[12] concluded that "a grading system for maceration has limited value, since it does not provide a precise correlation with the time lapse between intrauterine death and birth." Furthermore, the influence of factors other than the intrauterine retention interval has not been experimentally explored, yet Wigglesworth[9] stated that the changes of maceration can be accelerated by factors other than the time of fetal death. In particular, he noted that brown skin discoloration develops early in extremely premature fetuses and that desquamation proceeds more rapidly in hydropic fetuses. Although the conclusions of these perinatal authorities concerning fetal maceration have been widely accepted, data confirming the statements have not been published.

We conducted the current study to develop experimentally gross criteria for timing fetal death. Among the eight gross features identified, those that appeared to function best all involved desquamation (maximum diameter, percentage of the body surface, region involved by desquamation, and severity of desquamation). Gross changes that pertain to desquamation may perform well as diagnostic tests for the length of intrauterine retention because these changes can be assessed objectively. The least reliable of the eight gross features appeared to be those involving discoloration of the skin or umbilical cord; most incorrect predictions among the test fetuses involved a single false-positive finding based upon color. The explanation for these errors may relate to the subjective nature of color evaluation; umbilical cord and skin color were the least reproducible of the eight gross features assessed based on intra- and inter-observer agreement and kappa values. Alternatively, discoloration may be influenced by variables other than the death-to-delivery interval, as previously suggested by Wigglesworth.[9] When the 26 test cases were analyzed independent of skin and cord color, 85% of cases were correctly assigned to their clinically documented intrauterine retention intervals.

Several limitations of this study deserve comment. First, because this study is retrospective in design, the findings need to be validated in a prospective study. Second, the fetuses in this study were a heterogeneous group regarding the cause of death, gestational age at the time of death, and the presence of infection, hydrops, and stress. Although our analysis of these

variables identified only hydrops as a possible major accelerating influence, it is likely that other factors not yet identified can significantly affect the progression of maceration. Variables not assessed in this study that may influence maceration include the duration of ruptured membranes and the length of time from birth until fetal refrigeration.

Third, this study used photographs of fetuses, rather than the actual fetuses, for assessment of the gross changes of maceration. Because of this, certain postmortem changes (ie, skin slippage) could not be studied, all body surfaces could not be examined, and the possibility of artifacts relating to photography could not be entirely discounted. However, the retrospective photographic methodology allowed a large number of stillborn fetuses with well-timed deaths to be collected and assessed by two pathologists over a brief period.

In this retrospective study, we attempted to identify gross fetal changes developing after intrauterine death that may be used to time fetal death. Although the eight gross criteria identified were capable of correctly determining the approximate time of death in most cases, further investigation is necessary to assess the usefulness of these proposed criteria in other fetuses. Finally, although gross fetal examination alone has been demonstrated to have a moderate predictive value concerning the time of fetal death, it is likely that the performance of a complete fetal autopsy and placental examination (in addition to an external examination) will augment the pathologist's ability to estimate retrospectively the correct time of fetal death.

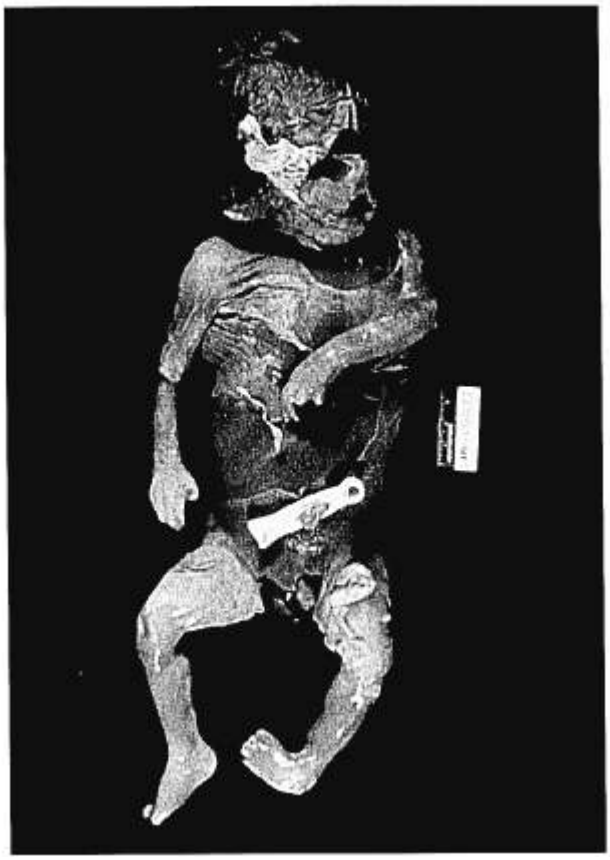

Figure 4. 30-week fetus who died between 288–456 hours before birth. Severe desquamation is seen, consistent with at least 24 hours of intrauterine retention; mummification is absent, suggesting a retention of less than 2 weeks (336 hours).

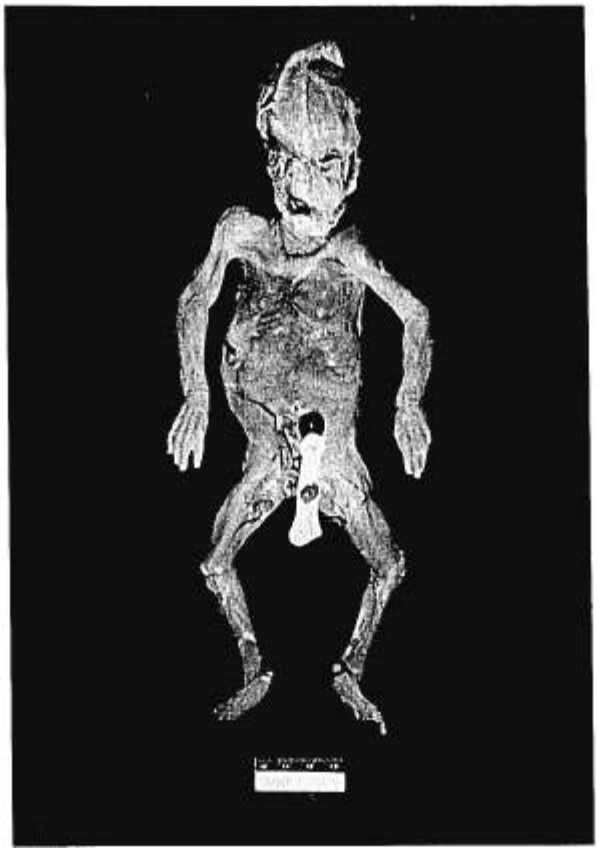

Figure 5. 24-week fetus (284 g) who died between 8–12 weeks before birth. The skin is tan in color and extensive mummification is seen, consistent with at least 2 weeks (336 hours) of intrauterine retention after fetal death.

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