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Infant Survival After Cesarean Section for Trauma

John A. Morris, Jr., M.D.,* Todd J. Rosenbower, M.D.,* Gregory J. Jurkovich, M.D.,†
David B. Hoyt, M.D.,‡ J. Duncan Harviel, M.D.,§ M. Margaret Knudson, M.D.,‖
Richard S. Miller, M.D.,¶ Jon M. Burch, M.D.,# J. Wayne Meredith, M.D.,**
Steven E. Ross, M.D.,‡‡ Judith M. Jenkins, R.N., M.S.N.,* and John G. Bass, B.A.*

From the Department of Surgery, Division of Trauma and Surgical Critical Care, Vanderbilt University Medical Center, Nashville, Tennessee; Department of Surgery, Harborview Medical Center,† Seattle, Washington; Department of Surgery, San Diego Medical Center,‡ San Diego, California; Department of Surgery, Washington Hospital Center,§ Washington, District of Columbia; Department of Surgery, San Francisco General Hospital,‖ San Francisco, California; Department of Surgery, Greenville Hospital Systems,¶ Greenville, South Carolina; Department of Surgery, Denver General Hospital,# Denver, Colorado; Department of Surgery, Bowman Gray Medical Center,** Winston-Salem, North Carolina; and Department of Surgery, Cooper Hospital,‡‡ Camden, New Jersey*

Hypothesis
Emergency cesarean sections in trauma patients are not justified and should be abandoned.

Setting and Design
A multi-institutional, retrospective cohort study was conducted of level I trauma centers.

Methods
Trauma admissions from nine level I trauma centers from January 1986 through December 1994 were reviewed. Pregnant women who underwent emergency cesarean sections were identified. Demographic and clinical data were obtained on all patients undergoing a cesarean section. Fetal distress was defined by bradycardia, deceleration, or lack of fetal heart tones (FHTs). Maternal distress was defined by shock (systolic blood pressure < 90) or acute decompensation. Statistical analyses were performed.

Results
Of the 114,952 consecutive trauma admissions, more than 441 pregnant women required 32 emergency cesarean sections. All were performed for fetal distress, maternal distress, or both. Overall, 15 (45%) of the fetuses and 23 (72%) of the mothers survived. Of 33 fetuses delivered, 13 had no FHTs and none survived. Twenty infants (potential survivors) had FHTs and an estimated gestational age (EGA) of greater than or equal to 26 weeks, and 75% survived. Infant survival was independent of maternal distress or maternal Injury Severity Score. The five infant deaths in the group of potential survivors resulted from delayed recognition of fetal distress, and 60% of these deaths were in mothers with mild to moderate injuries (Injury Severity Score < 16).

Conclusions
In pregnant trauma patients, infant viability is defined by the presence of FHTs, estimated gestational age greater than or equal to 26 weeks. In viable infants, survival after emergency cesarean section is acceptable (75%). Infant survival is independent of maternal distress or Injury Severity Score. Sixty percent of infant deaths resulted from delay in recognition of fetal distress and cesarean section. These were potentially preventable. Given the definition of fetal viability, our initial hypothesis is invalid.

Trauma in pregnancy—one patient but two lives at risk, two lives inexorably woven in a complex drama played on a stage of unique physiology, rare syndromes, and specialized equipment. The script demands that complex, medical, ethical, and economic decisions be made in a limited time frame with inadequate data and discussion.

Although much has been written about trauma and pregnancy,[1-18] most publications address the issues of resuscitation and the problems of fetal teratogenesis.[19] Few studies address the clinical issues of trauma in the third trimester of pregnancy, including indications and outcome of emergency cesarean sections[7,16,20-22] or perimortem cesarean sections[20,23-26] for trauma victims.

Because the third trimester trauma patient is rare,[27] we designed a multi-institutional study incorporating data from nine level I trauma centers to address the following hypothesis: Emergency cesarean section after trauma is rare, the outcome is dismal, and the procedure should be abandoned. Additionally, we sought to define a clinical algorithm integrating evolving trends in high-risk obstetrics and neonatology to provide the practicing clinician assistance with the difficult decision process accompanying these unique patients.

METHODS

During the 10-year period from January 1, 1986, through December 31, 1994, we retrospectively reviewed admissions to nine designated level I trauma centers: Vanderbilt University Medical Center; Harborview Medical Center; the University of California, San Diego Medical Center; Washington Hospital Center; San Francisco General Hospital; Greenville Hospital Systems; Denver General Hospital; Bowman Gray Medical Center; and Cooper Hospital/University Medical Center. The number of pregnant trauma patients and emergency cesarean sections was recorded. Pregnancy was confirmed by history and physical examination, positive pregnancy test, or ultrasound. The variables collected on women who underwent cesarean section included mechanism of injury; maternal age; estimated gestational age (EGA), by dates or ultrasound; time between injury and arrival at the trauma center; time between injury and cesarean section; time between maternal cardiac arrest and cesarean section, where applicable; admitting maternal systolic blood pressure; presence of fetal heart tones (FHTs); indication for cesarean section (fetal distress, maternal distress, or both); Injury Severity Score (ISS)[28]; Glasgow Coma Scale[29]; diagnostic tests; and maternal and infant outcome, short and long term. Short-term outcome was defined by the condition of the patients (both mother and infant) at discharge, whereas long-term outcome was the condition recorded at the most recent follow-up examination.

Fetal distress was defined as bradycardia (fetal heart rate < 100), prolonged deceleration (>60 seconds), or lack of FHTs. Maternal distress was defined as shock (systolic blood pressure < 90) or acute decompensation. The group of potentially salvageable infants was defined by the presence of FHTs and an EGA of greater than or equal to 26 weeks. Perimortem cesarean section indicates an emergency cesarean section performed during maternal cardiopulmonary resuscitation.

Descriptive statistics were performed on the data. Means were compared using the Student's t test. Chi square test and Fisher's exact test were used to identify variables that significantly influenced fetal and maternal outcome. Statistical significance was defined by a p value less than or equal to 0.05.

RESULTS

There were 114,952 consecutive admissions to 9 level I trauma centers that were reviewed. More than 441 pregnant female trauma patients were identified (Fig. 1). Thirty-two of these pregnant trauma patients underwent cesarean sections and delivered 33 fetuses. Clinical data on the maternal group (N = 32) are illustrated in Table 1. Overall, 15 of 33 fetuses (45%) survived, and 23 (72%) of the mothers survived. Of the 32 cesarean sections performed, 19 (59%) were done for fetal distress, with 20 infants being delivered, 4 cesarean sections (13%) were done for maternal distress, and 9 cesarean sections (28%) were done for both fetal and maternal distress.

Maternal Outcome

Twenty-three of 32 mothers (72%) survived. Twenty-nine mothers (91%) had blunt trauma. Table 2 describes the anatomic and physiologic variables associated with maternal presentation. A mean ISS of 25 attests to the magnitude of injuries sustained by this group of mothers. Six patients had an ISS of 25 to 39, and 3 patients had an ISS greater than 40. Factors expected to affect outcome in the nonpregnant patient affected outcome in the pregnant patient. These included maternal ISS, Glasgow coma score, and shock on admission ($p < 0.05$). Figure 2 relates maternal mortality to maternal ISS and is com-

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Address reprint requests to John A. Morris, Jr., M.D., Division of Trauma and Surgical Critical Care, 243 Medical Center South, 2100 Pierce Ave., Nashville, TN 37212.

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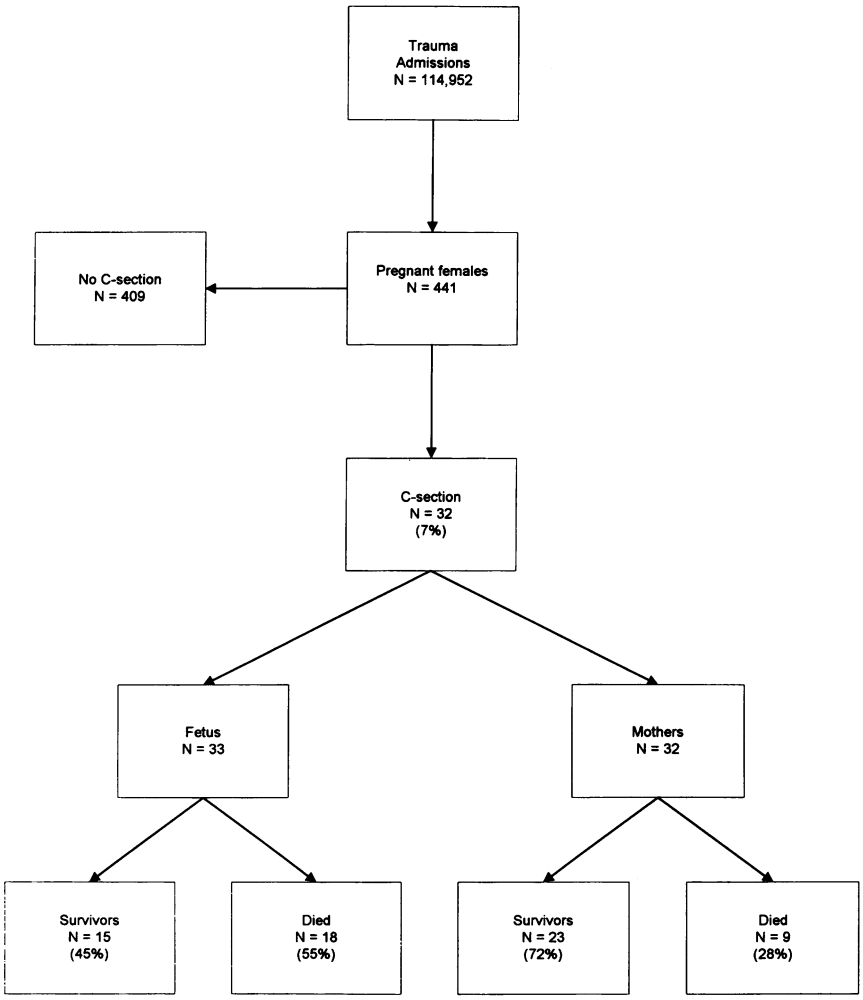

Figure 1. Flow diagram of 114,952 consecutive trauma admissions yielding more than 441 pregnant female patients, 32 of whom underwent cesarean section for trauma, delivering 33 infants (including one set of twins).

patible with published age-specific norms.[30] Long-term maternal follow-up was available in 15 of 23 survivors (65%). Of these, 13 patients are alive and well (mean follow-up, 14 months; range, 1 to 43 months). One patient is quadriplegic, and one patient has a post-traumatic seizure disorder.

Fetal Outcome

Thirty-three fetuses, including 1 set of twins, were delivered and 15 survived (45%). However, 13 of 33 fetuses (39%) had no FHTs. There were no survivors in this group, and for analysis, this group was considered unsalvageable. Three fetuses had a gestational age of less than 26 weeks; none of these fetuses had FHTs and were not considered viable. Consequently, 20 infants were considered potentially salvageable for this analysis.

Three perimortem cesarean sections were performed during maternal cardiac arrest. These procedures were completed within 10 minutes after the initiation of car-

Table 1. MATERNAL CLINICAL DATA (N = 32)

	Mean ± SEM	Range
Maternal		
Age (yr)	25.2 ± 1.1	17–37
Admission SBP (mmHg)	101.2 ± 6.1	0–160
ISS	25.1 ± 2.9	3–75
GCS	11.4 ± 0.9	3–15
Infant		
EGA (wk)	32.5 ± 0.8	22–40
Time to C-section (hr)*	5.6 ± 1.7	0.25–48
Mechanism of injury [no. (%)]		
Blunt	29 (91)	
Penetrating	3 (9)	

EGA = estimated gestational age; SBP = systolic blood pressure; C-section = Cesarean section; ISS = Injury Severity Score; GCS = Glasgow Coma Score; SEM = standard error of the mean.
* N = 30; two values unknown.

Table 2. VARIABLES AFFECTING MATERNAL OUTCOME

	Outcome		
	Live (n = 23) [mean ± SEM (range)]	Die (n = 9) [mean ± SEM (range)]	p Value
Maternal			
Age (yr)	25.5 ± 1.4 (17–37)	24.2 ± 1.4 (19–30)	0.515
Admission SBP (mmHg)	112.9 ± 4.3 (70–160)	80.7 ± 12.5 (0–124)	0.004
ISS	20.2 ± 1.0 (3–75)	37.6 ± 3.7 (21–50)	0.006
GCS	13.4 ± 0.8 (1–18)	6.3 ± 1.7 (3–15)	≤0.001
Infant			
EGA (wk)	32.2 ± 1.0 (22–40)	33.3 ± 1.6 (26–40)	0.542
Time to C-section (hours)*	4.2 ± 1.0 (1–18)	9.3 ± 5.8 (0.25–48)	0.186
Mechanism of injury [no. (%)]			
Blunt	22 (96)	7 (78)	0.184
Penetrating	1 (4)	2 (22)	

EGA = estimated gestational age; SBP = systolic blood pressure; C-section = Cesarean section; ISS = Injury Severity Score; GCS = Glasgow Coma Score; SEM = standard error of the mean.
* N = 30; two values unknown.

diopulmonary resuscitation. Mean maternal ISS was 42 (range, 33 to 50) and all 3 mothers died. The one infant who had FHTs survived. At 9-month follow-up, this infant had retinopathy of prematurity and right-sided hearing loss, but was otherwise doing well.

The group of 20 infants who had FHTs and an EGA of greater than 26 weeks was considered potentially salvageable. Fifteen infants survived (75%) and 5 infants died. Of the five infants with an EGA of 26 to 28 weeks, four survived (80%) (Fig. 3). Table 3 provides the clinical variables for survivors and nonsurvivors. Of the 5 infants who died, 3 of the 5 deaths occurred in mothers with a minimal ISS (<16) who had been observed for more than 2.5 hours before cesarean section. The other two deaths occurred in mothers with massive injuries. One mother was *in extremis* at the time of the cesarean section and died on the operating table. The infant also was *in extremis,* with a fetal heart rate of 20 before arrival in the operating room. All five fetal deaths were associated with fetal distress at the time of cesarean section.

Figure 4 shows that mortality is independent of maternal ISS in infants having FHTs. Maternal Glasgow coma score, an indicator of severity of head injury, had no bearing on infant survival.

Long-term infant outcome was available in 7 of 15 survivors (47%). Four (57%) of these children are alive, well, and without chronic disease. Of the three remaining children, one (age, 14 months) has chronic lung disease, one

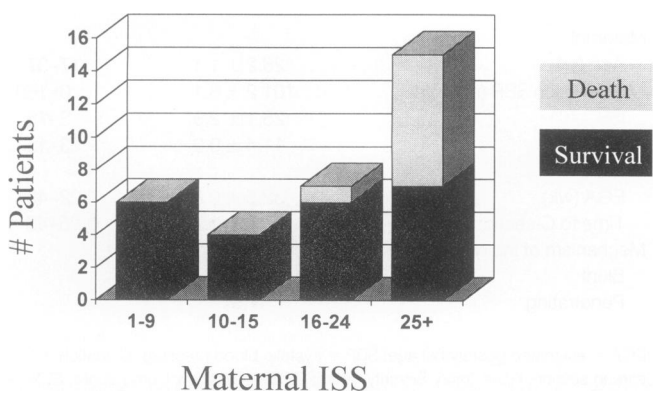

Figure 2. Maternal mortality by Injury Severity Score demonstrates that maternal injury adjusted mortality is compatible with established norms.

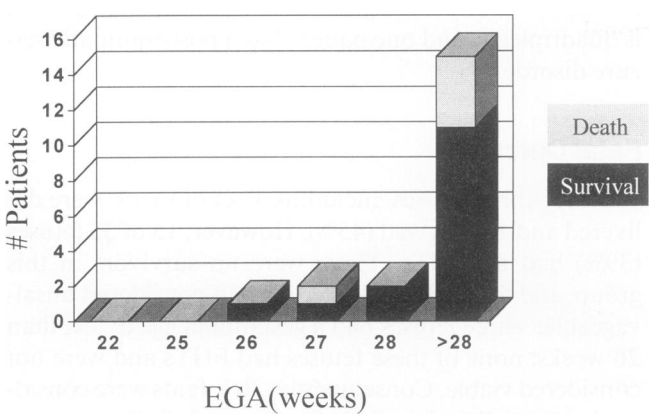

Figure 3. Salvageable infant survival *vs.* estimated gestational age. At gestational age less than 26 weeks, no infants survived. However, at a gestational age between 26 and 28 weeks, the survival rate increases to 80%.

Table 3. CLINICAL VALUES OF SALVAGEABLE INFANTS (N = 20)

	Outcome	
	Live (n = 15) [mean (range)]	Die (n = 5) [mean (range)]
Maternal		
ISS	25.6 (3–75)	16.8 (4–34)
GCS	10.3 (3–15)	15
Admission SBP (mmHg)	103.9 (72–148)	104 (60–124)
Age (yr)	25.5 (17–35)	24 (20–34)
Infant		
EGA (weeks)	31.5 (26–40)	33.8 (27–36)
Time to C-section (hr)	8.4 (1–84)	5.19 (0.25–18)

EGA = estimated gestational age; SBP = systolic blood pressure; C-section = Cesarean section; ISS = Injury Severity Score; GCS = Glasgow Coma Score; SEM = standard error of the mean.

(age, 9 months) has right-sided hearing loss, and one (age, 3.5 years) has hypothyroidism, right-sided cerebral palsy, blindness, chronic lung disease, and developmental delay.

DISCUSSION

Trauma during pregnancy is rare, occurring in 6% to 8% of pregnant women.[31] Although uncommon, trauma is associated with an increased risk of spontaneous abortion,[7,32] preterm labor,[33] abruptio placenta,[17,27,34,35] fetomaternal transfusion,[36] and fetal death.[6,35,37–41] The management of both the mother and the fetus after trauma is dependent on the magnitude of injury[6,37]; uterine, placenta, and fetal physiology[5,9,42]; and the gestational age of the fetus.[43] Recent advances in the fields of traumatology, neonatology, and high-risk obstetrics have created both confusion in the literature and opportunity to improve outcome. For instance, the evolving definition of fetal viability complicates decision making.[43] One of the most difficult decision processes in medicine occurs when the life of the mother and the life of the fetus are intertwined and the physician must adjudicate between the two.

Although there are many reports of trauma in pregnancy, only one study focuses on the problems of third-trimester management and the role of emergency cesarean sections.[37] Our study attempts to define "the potentially salvageable infant" and create a rational treatment algorithm for both emergency cesarean sections and perimortem cesarean sections after trauma.

The Salvageable Infant

The most important finding to emerge from this study is the definition of a subgroup of infants who are potentially salvageable. In this group of patients, defined by an EGA greater than or equal to 26 weeks and the presence of FHTs, the survival rate was 75%. Survival was independent of maternal distress, but clearly related to the presence of fetal monitoring and early recognition of fetal distress. There were no survivors in fetuses having no FHTs. This supports the premise that fetal viability is directly related to the presence or absence of FHTs on admission. As such, the presence of FHTs is a simple, rapid, reproducible, and profoundly important marker of fetal viability. We recommend that the Doppler assessment of FHTs be elevated to a component of the primary survey performed on trauma patients during the third trimester of pregnancy. This should be accomplished simultaneously with the assessment of maternal circulatory integrity during the ABC's of the trauma resuscitation.[44] If FHTs are absent, the pregnancy should be ignored and treatment directed solely at maternal survival.

Data from leading neonatal centers in the nontrauma setting show that survival of infants born from 23 to 25 weeks' gestation increases with each additional week of gestation.[45,46] However, the overall neonatal survival rate for infants born during this early gestational period remains less than 40% (Table 4). Of those who survived, approximately 40% have moderate to serious disabilities and many have neurobehavioral dysfunction and poor school performance.[43] The commitment for all aspects of care may be extensive, multidisciplinary, lifelong, and costly. Although it is ideal to inform the prospective parents regarding fetal outcome and the financial and emotional consequences of profound prematurity, this is not possible in the trauma setting where the patients are of-

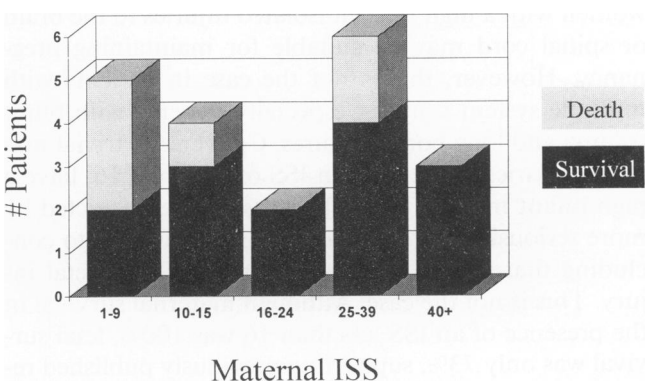

Figure 4. Salvageable infant survival *vs.* maternal Injury Severity Score (ISS). Infant death is distributed across the spectrum of severity and even the most injured mothers (ISS > 40) have good infant survival.

Table 4. NEONATAL SURVIVAL BY GESTATIONAL AGE*

Age (wk)	1987–1988 [mean % (range)]	1989–1990 [mean % (range)]
23	23 (0–33)	15 (0–29)
24	34 (10–57)	54 (27–100)
25	54 (30–72)	59 (47–74)

* Rates were reported by the National Institute of Child Health and Human Development neonatal centers.

ten critically ill or sedated, families are unavailable, and the decision-making process is obscure. Consequently, it is our recommendation that fetal viability in the trauma patient be defined at age 26 weeks. This recommendation changes the previous recommendations in the literature from 28 weeks,[22] because four of five infants (80%) with an EGA of 26 to 28 weeks survived in this series.

This study also shows that even in the most profoundly injured mother, manifested by an ISS greater than 25, fetal survival was 78%. This same critically ill population had a maternal survival rate of only 44%, illustrating the need for emergency cesarean section at the first indication of fetal distress. Recognition of fetal distress is critical. In this study, fetal distress was defined as a fetal heart rate of less than 100, prolonged deceleration for more than 60 seconds, or recurrent late decelerations. Evaluation of these parameters on cardiotocographic monitoring (CTM) requires significant expertise. The decision-making process leading to cesarean section must incorporate input from the traumatologist, emergency medicine physician, obstetrician, and the pediatrician. The management issues that must balance the needs of both the mother and infant are complex and underscore the need for teamwork.

Anecdotal experience from this study suggests that women with a high ISS but isolated injuries to the brain or spinal cord may be suitable for maintaining pregnancy. However, this is not the case in patients with multiple system injuries, especially patients with blunt trauma and long bone fractures. Conversely, trivial maternal injuries, defined as an ISS of less than 16, have a high infant mortality rate. It is easy to be distracted by more seriously injured patients or be seduced into concluding that minor maternal injury precludes fetal injury. This is not the case. Although maternal survival in the presence of an ISS less than 16 was 100%, fetal survival was only 73%, supporting previously published reports that even minor maternal injury can result in death of the fetus.[34] Of more concern was the finding that 60% of these infant deaths occurred in mothers with minor injury and delayed cesarean sections in the presence of fetal distress. This may well represent delayed recognition of fetal distress or delayed cesarean section in a misguided belief that the intrauterine environment is superior to delivery.

Except for maternal death,[47] the most common cause of fetal death after both major and minor trauma in pregnancy is abruptio placentae.[34] Although this series was not designed to address the incidence of abruption, studies suggest its incidence is approximately 5%.[15,35,48] This series also was not intended to determine the optimal duration of CTM.[47] However, it is clear that all patients with potentially salvageable infants require fetal monitoring.[47] This monitoring can be performed either using continuous CTM or interval Doppler evaluation of FHTs every 15 minutes.

Of the five fetal deaths in the potentially salvageable group, three deaths resulted from the failure of fetal monitoring. Because abruptio placentae is usually manifested shortly after injury, the literature supports fetal monitoring for a minimum of 4 hours and a maximum of 24 hours.[42] Sixty percent of our infant deaths should have been diagnosed for early emergency cesarean sections by fetal monitoring. Consequently, at our institution, we have a mandated 24-hour protocol for CTM after trauma.

Clinical Implications

The clinical implications of this study are outlined in Figure 5. The female trauma patient with a clinically gravid uterus should be immediately examined by Doppler for FHTs. If FHTs are absent, fetal demise has occurred and the pregnancy should be ignored. Maternal resuscitation should then proceed according to Advanced Trauma Life Support guidelines.[44] If FHTs are present, it is imperative to accurately predict fetal gestational age. Except in those cases of a moribund mother, EGA is best assessed in the emergency department using ultrasonography. If the EGA is less than 26 weeks, resuscitation should be directed at maternal survival. If, however, the EGA is greater than 26 weeks, the infant is potentially salvageable and should be monitored. Maternal evaluation can then progress according to Advanced Trauma Life Support standards. If CTM is not readily available, Doppler monitoring of FHTs every 15 minutes is advised. If signs of fetal distress occur or if there is evidence of maternal distress, emergency cesarean section should be performed immediately.

Perimortem Cesarean Section

Using these guidelines, the need for perimortem cesarean sections is extremely rare. In this series, only 1 pa-

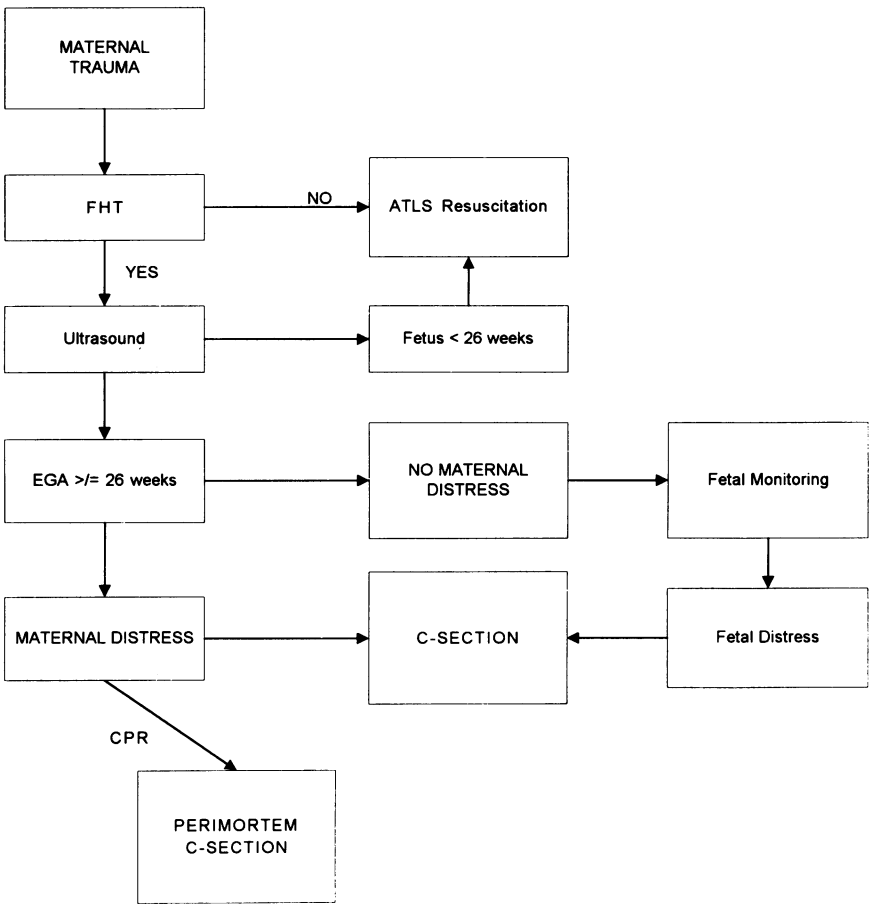

Figure 5. Clinical algorithm for emergency cesarean section and perimortem cesarean section. The pregnant trauma patient is assessed for fetal heart tone (FHT) and estimated gestational age (EGA). If FHT is present and EGA ≥ 26 weeks, fetal monitoring is required. Fetal or maternal distress mandates emergency cesarean section. Perimortem cesarean section is performed if cardiopulmonary resuscitation is in progress.

tient of the 114,952 trauma admissions had FHTs, EGA greater than or equal to 26 weeks, requiring maternal cardiopulmonary resuscitation. Although perimortem cesarean section involves minimal legal risk, it is not a trivial decision.

Perimortem cesarean section must not be delayed for ultrasonography. Before making the abdominal incision, the surgeon must ensure that fundal height is several finger breadths above the umbilicus, ensuring adequate gestational age. The appropriate incision for a perimortem cesarean section is from the xiphoid to the symphysis pubis through all layers of the abdominal wall and peritoneum. When the uterus is identified, a vertical uterine incision is made and if the placenta is anterior, it should be incised as well. To deliver the infant, the surgeon opens the uterus, clamps and cuts the cord, and begins infant resuscitation. Efforts at maternal resuscitation should continue simultaneously, as there are reported cases of maternal survival after the delivery of the infant.[25]

Although the observation that the presence of FHTs and an EGA of 26 weeks may seem trivial, these observations give clinical perspective to the literature and expedite the decision-making process in these complex patients. Future research must determine the optimal duration for CTM, define the threshold of maternal injury that mandates cesarean section, and develop a simple, sensitive, and specific test for abruptio placentae.

CONCLUSIONS

An infant who has FHTs at an EGA of 26 or more weeks is potentially salvageable, independent of maternal injury. Infants who meet these criteria have a survival rate of 75%, but long-term morbidity may be high. Infants who meet these criteria and are delivered by perimortem cesarean section can survive although the incidence is exceedingly rare.

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Discussion

DR. J. ALEX HALLER, JR. (Baltimore, Maryland): Mr. President, Mr. Secretary, Ladies, and Gentlemen. I appreciate the opportunity of having reviewed Dr. Morris's manuscript, not just for myself but, as he knows, he had two reviewers because my wife Emily, who is an obstetrician and in a high-risk pregnancy group, also greatly enjoyed the paper and has a few comments to be passed along to you, John, through me.