

# Prevention of Fetal Injury in Motor Vehicle Crashes

By: James E. Hofferberth

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## ABSTRACT

The fetus of a pregnant woman has been shown to be at 5 times the risk of a 0 to 1 year old child in the same car using standard, mandated restraint systems. Placental Abruptio is the most common cause of fetal death but the overall actual injury mechanisms are not well understood. Several methods of protecting the women's abdomen and fetus from the effects of lap and shoulder belt loading, pelvic submarining, steering wheel contact, air bag deployment, and anthropomorphic deformation and dislocations during crash events have been identified and patented. The biomechanics of the most common device types is examined using standard engineering analytical techniques. Particular attention is drawn to the side effect injuries expected with each type.

## REVIEWS

Albert I. King, PhD  
Distinguished Professor  
Department of Biomedical Engineering  
Wayne State University

“This is an excellent review of restraining devices for pregnant car occupants... Indeed, there is a need for such a paper.”

## INTRODUCTION

There was a significant increase in seat belt usage in the United States in the 1970's, along with the adoption of mandatory seat belt usage laws by most states. Although it was known at that time that the lap and shoulder belts posed a significant unintended injury risk to the unborn children of pregnant women [1], over time it has been demonstrated that the lap and shoulder belt system provides a significant improvement in fetal safety relative to the situation where the mother does not use the lap and shoulder belt restraints. However current data shows that risk to the fetus is still elevated, on the order of 5 times greater than the risk to a 0 to 1 year old sibling riding in the same car.[2]

The objective of this study is to review the various approaches that have been identified by the United States Patent and Trademark Office, Washington, DC (USPTO), for reducing the risk of fetal injury and death in motor vehicle crashes and other vehicle motions that pose a risk to the fetus.

## STUDY OF PREGNANT WOMEN IN AUTOMOBILE CRASHES

Automobile crashes and the accompanying changes in velocity ( $\Delta v$ ) impart forces to vehicle occupants that are directly correlated to injury. These changes can result from the forces of impact with other objects and other motor vehicles. Abrupt changes of motion also result from minor impacts, emergency braking or maneuvering, loss of control, and rollover crashes.

The occupants of a vehicle that is undergoing abrupt motion changes must respond in a manner that keeps the person inside the car throughout the event. If the person is unrestrained within the vehicle, the forces required to contain the occupant are applied by uncontrolled impacts with various objects and surfaces in the vehicle. These uncontrolled impacts were the root cause of the injuries that typified vehicle crashes in the 1950's and 1960's.

Various restraint systems were introduced to control the motions of the passenger within the vehicle in ways that reduce the propensity for injury. Many configurations were tried ranging from a simple lap belt up to the fully integrated belt/air bag restraints common in today's production cars. All of these configurations apply surface forces to the occupant's body in an attempt to contain the occupant within the vehicle while reducing the propensity for injury or death.

The use of surface forces necessarily introduces stresses within the body. These stresses can cause serious injury, and cannot be eliminated.

belts remain as very serious problems.

There are basically two ways to apply the required surface forces to the body while reducing the propensity for injury. The first approach is to attempt to concentrate the required forces on stronger skeletal structures of the body, such as the knees, pelvis, shoulders, and ribs. This is the approach that is utilized by virtually all belt type restraints. They all suffer from the results of attempting to control whole body motion by applying force only the skeleton. This approach is effective as crash severity increases only up to the point where the stresses induced between the skeletal segments and the surrounding body tissues and other internal stresses exceed tolerable limits. As a result, in more severe crashes the use of lap and shoulder belts is associated with significant side effect injuries commonly referred to as “Seat Belt Syndrome” injuries.

“The seat belt syndrome consists of skeletal, soft-tissue, and visceral injuries associated with use of two- and three-point restraints in patients involved in motor vehicle accidents. Skin abrasions of the neck, chest, and abdomen--the classic seat belt sign--indicate internal injury in 30% of cases. Neck abrasions are associated with injuries to the carotid artery, larynx, and cervical spine; chest abrasions, with fractures of the sternum, ribs, and clavicles and injuries to the heart and thoracic aorta; and abdominal abrasions, with mesenteric tears, bowel perforation and hematoma, Chance fractures, and injuries to the abdominal aorta.” [3]

Seat belt syndrome injuries are caused primarily by the concentration of shoulder belt forces on the upper torso, the lap belt loads that are applied to the lower abdomen and pelvis and the natural tendency of the pelvis to submerge under the lap belt.

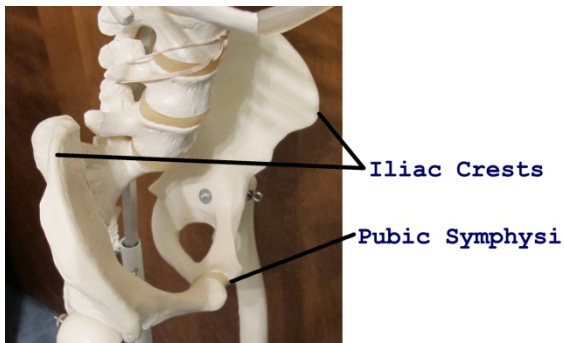
One countermeasure to submarining that is in common usage is to control knee impact against the lower dash board or knee airbag to prevent excessive forward motion of the legs, and thereby reduce the likelihood of submarining. Some car seats have also been configured to help reduce the likelihood of submarining. However seat belt syndrome injuries from both the lap and shoulder

The second approach to the application of surface forces by restraint systems is to attempt to distribute the required forces over the surface of the body in a way that reduces internal stresses. This is the approach that is used by airbag restraints, padding configurations, and other load distributing devices. These devices all suffer from the necessity to be in close proximity to the surface of the body to be fully effective. This need for proximity conflicts with the person’s need for mobility within the vehicle during normal operations. Such devices must either be deployed during the event, as air bags are, or located at a distance from the body surface, which allows significant impact velocities to develop before contact. Deployment of such devices during the crash requires high energy levels to be introduced, which inherently represent a potential injury mechanism. All surface distribution approaches suffer from this conflict between the need for free motion in normal operations, and the close proximity required for full effectiveness in a crash.

Current practice is to use a combination of both load concentration on skeletal structures and load distribution on other areas of the body. Lap and shoulder belts are used in combination with inflatable air bags and stationary padded surfaces in these systems. However the use of these approaches for pregnant women introduces additional complications because of the presence of the fetus in the woman’s abdomen. To examine these effects, we start with a detailed look at the anatomy of a pregnant woman.

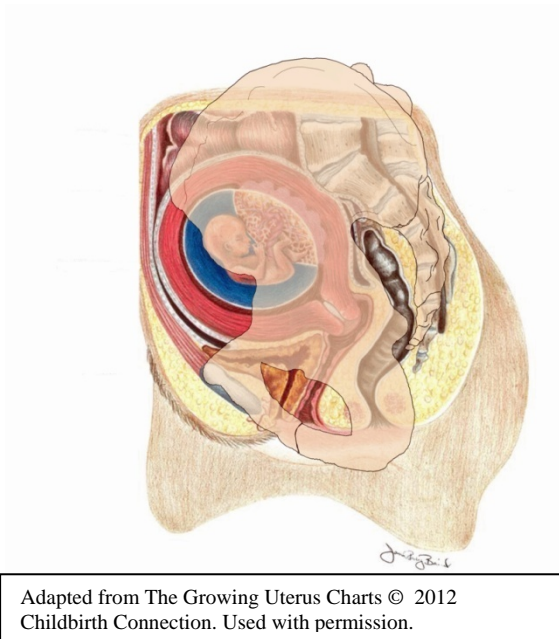
## THE CHANGING ANATOMY OF A PREGNANT WOMAN

During early pregnancy, the uterus is mostly contained within the outer profile of the pelvis. It is protected by the pelvis from the rear, but the front is not protected from penetration. The only bony structures that project forward of the uterus are the pubic symphysis and the two iliac crests. Application of force to the uterus is possible between these three points as shown in Figure 1.



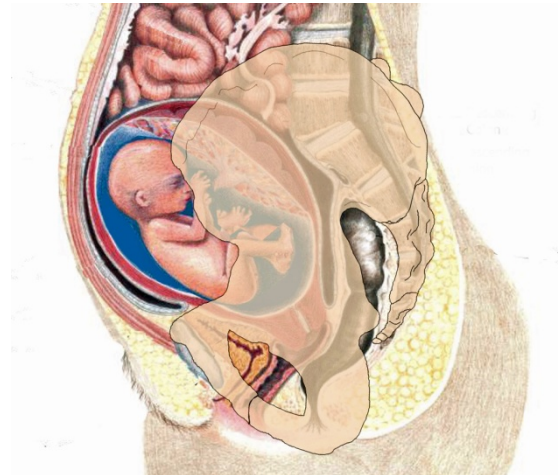
**Figure 1 Iliac Crests and Pubic Symphysis**

At 12 weeks, the fetus is typically oriented head-upward in the uterus as shown in Figure 2.



**Figure 2 Head Upward at 12 Weeks**

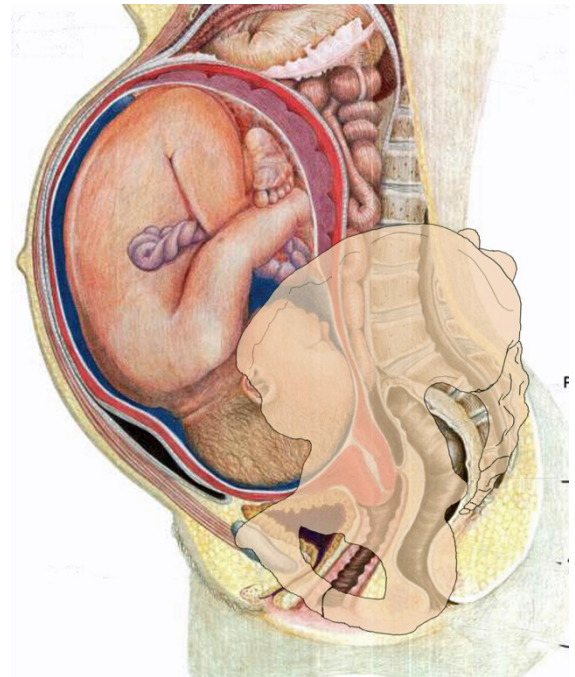
At 20 weeks, the uterus and head extend forward of the anterior extremis of the pelvis, as shown in Figure 3. The baby has no frontal protection at all other than soft abdominal tissues.



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**Figure 3 Head Up at 20 Weeks**

At 36 weeks, the baby has typically dropped to a head-downward position as shown in Figure 4. The head will eventually be “locked” in the pelvic saddle, and virtually the entire body of the baby other than the top of its head will extend forward and upward of the pelvis.



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**Figure 4 Baby Forward of the Pelvis at 36 Weeks**

## ANTHROPOMORPHIC TEST DUMMY SIMULATION OF PREGNANT WOMEN

The earliest test dummy simulation of a pregnant woman was developed by in 1996. [4] This dummy was constructed by adding a pregnant-shaped abdomen to a then existing 5th Percentile Female Crash Test Dummy. Load cell(s) were located behind the simulated pregnant abdominal insert, and the upper torso was fitted with an outer skin resembling that of a small pregnant woman. This device was used by General Motors to study the relative intensity of belly slap caused by various air bag configurations.

A second attempt to build an anthropomorphic crash test dummy simulating a pregnant woman was developed by the University of Michigan Transportation Research Institute (UMTRI). [5] The UMTRI dummy was referred to as the “MAMA-2B” dummy. It was evaluated in a series of sled tests with belt type restraint systems. The MAMA-2B was equipped with a water-filled abdominal bladder. Several transducers were installed, including two pressure transducers located at the anterior and posterior extremes of the water-filled bladder. UMTRI reported that only the anterior pressure transducer produced meaningful data, and this data was correlated with the severities of the tests. It was then attempted to correlate these pressure readings with real world data to show a positive correlation between the measured pressures and injury in real world impacts.

It is instructive that only the anterior pressure transducer produced meaningful data. The absence of meaningful data from the posterior pressure transducer suggests that there was no measurable increase in the static pressure in the abdominal insert. This suggests that the pressure measured by the anterior transducer resulted primarily from the natural pressure gradient, increasing from aft–forward, that develops in a non-compressible fluid when exposed to an acceleration field, such as the crash acceleration pulse of the test.

That these pressures correlate with test severity is to be expected since the array was effectively providing a surrogate measure of test severity. The absence of meaningful data from the aft transducer suggests that the seat belts used in the tests had little effect on the pressure in the abdominal insert. Thus the correlation between these measured pressures and real world injury severity caused by the belts represents only a covariance with crash severity. It did not produce meaningful results relative to the interactions between the belts and the pregnant abdomen. Any acceleration transducer on the sled, or even the sound levels in the lab during the tests would show a similar correlation with test severity, and it would have little to do with injury to the abdomen.

To date there is no test dummy surrogate whose response can credibly be correlated with the propensity of fetal injury with various restraint configurations. The absence of such a test device is implicit in several efforts to study the material properties of critical body tissues in the pregnant abdomen to allow microscopic or cellular level analytical modeling of important abdominal injury mechanisms.

## ANALYTICAL MODELING OF ABDOMINAL INJURY

The first step in building an analytical model of abdominal injury to a pregnant woman is to determine the material properties and dynamic response characteristics of the body tissues that are involved. This is axiomatic for the development of both physical surrogates (test dummies) and mathematical surrogates. This is a significant obstacle given that injury level testing on pregnant women is not possible.

In the development of test dummies, this paradox is typically by-passed by the use of physical structures that resemble human body parts in a very gross way. For example, the steel head of a crash test dummy resembles the shape of the human head, but its physical characteristics, and more importantly its

dynamic responses, are entirely different. This greatly limits the use of the test dummy head for detailed study of the various mechanisms of head injury, and only gross overall acceleration response was used to establish the Head Injury Criteria at a macroscopic level. This limitation has spawned extensive study and modeling of the microscopic material properties and dynamic responses of the human head. This work has not yet produced either usable test devices or injury criteria related to crash impact injury to the head.

In the study of fetal injury, attempts have been made to determine the physical properties of the tissues and structures of the pregnant uterus. Dr. Mark Pearlman of the University of Michigan Medical Center has subjected postnatal samples of these materials to testing to determine their material properties, and has produced some very interesting results. These results have not yet been implemented in the development of physical models that are useful in the study of placental injury in automobile crashes. [6] & [7].

## **ENGINEERING ANALYSIS OF PREGNANT WOMEN IN AUTOMOBILE CRASHES**

There is virtually no information available about the response of live pregnant women in automobile crashes. Field data has been collected, but the efforts are limited by the fact that there is normally no record made of fetal outcome. The data that is available has been inferred from the narrative discussions of accident reports from several states [2].

Direct laboratory study of the injury mechanisms associated with pregnant women and their unborn children is not possible. However, it is possible to study the known anatomical structures of the pregnant woman relative to the known properties of existing restraint schemes. This type of analysis is aided by the study of crash testing that has been conducted with animal, cadaver and human subjects

in the past. Although no such data is available for pregnant women, data is available from laboratory testing with volunteer human males, cadavers and several types of animals including testing with pregnant baboons. [1] The response of a pregnant woman must be inferred from these data.

## **THE BIOMECHANICS OF LAP AND SHOULDER BELTS**

There is extensive data on the gross response of animal, cadaver and human test subjects with lap and shoulder belt type restraint systems. The test results with cadaver, human volunteer and pregnant baboon test subjects are particularly relevant to the pregnant woman.

Male human volunteers have been exposed to simulated frontal crash testing to severities up to 17 MPH delta v. The typical response is characterized by several familiar events as follows;

1. As the crash begins the body continues moving forward relative to the seat until the lap and shoulder belts develop meaningful restraining force.
2. The head flexes forward and downward until the chin impacts the chest.
3. The legs continue to pull forward tending to cause the pelvis to initiate submarining under the lap belt.
4. The ribs wrap themselves around the shoulder belt as the free arm and shoulder flex over the belt with the head and neck. The lower ribs and abdomen attempt to extrude between the lap and shoulder belt.

Figure 5 shows a 17 MPH impact test with a human volunteer at approximately maximum forward motion relative to the seat. It should be noted that the subject was in very good physical condition, provided with a solid foot support, and he was awake and fully braced before the test started. This

is the onset of submarining of the pelvis under the belt, and it was the pain limit for these volunteer test subjects



**Figure 5 Human Volunteer, Lap and Shoulder Belts at 17 MPH (Video available at <http://www.jimhof.com/TestVideos.html>)**

Male cadavers have been exposed to simulated frontal crash testing to severities in excess of 30 MPH. The typical responses as shown in Figures 6 and 7 are similar to, but much exaggerated over those experienced in the human volunteer tests with lap and shoulder belts.



**Figure 6 Cadaver 1 with Lap and Shoulder Belts at 35 MPH (Video available at <http://www.jimhof.com/TestVideos.html>)**

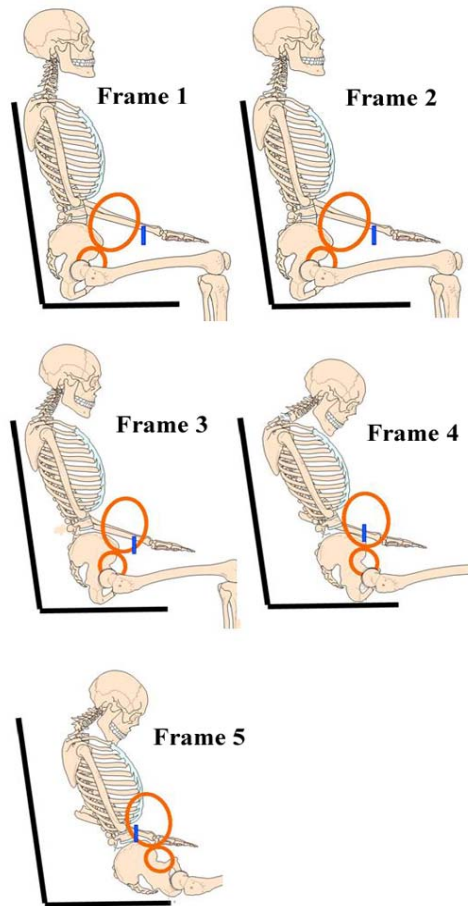


**Figure 7 Cadaver 2 Lap and Shoulder Belts at 35 MPH (Video available at <http://www.jimhof.com/TestVideos.html>)**

It should be noted that these male cadavers were typical of normal body density (not obese), and of course they were not pregnant. The distension of the abdomen between the lap and shoulder belts is evident. This type of distension for a pregnant woman would be exacerbated by the additional mass of the pregnant abdomen. Submarining is also evidenced by the location of the white crotch of the upper body suit.

A mechanism of pelvic submarining under the lap belt is illustrated in Figure 8. Frame 1 shows the normally seated skeleton and the approximate position of a late term fetus. The head is “locked” in the pelvic cradle in preparation for a normal childbirth. In Frame 2 the skeleton has started moving forward relative to the seat and lap belt, which is shown in blue. The legs have pulled the lower pelvis forward as it begins to rotate under the lap belt. The horizontal position of the lap belt relative to the seat remains fixed throughout the sequence.

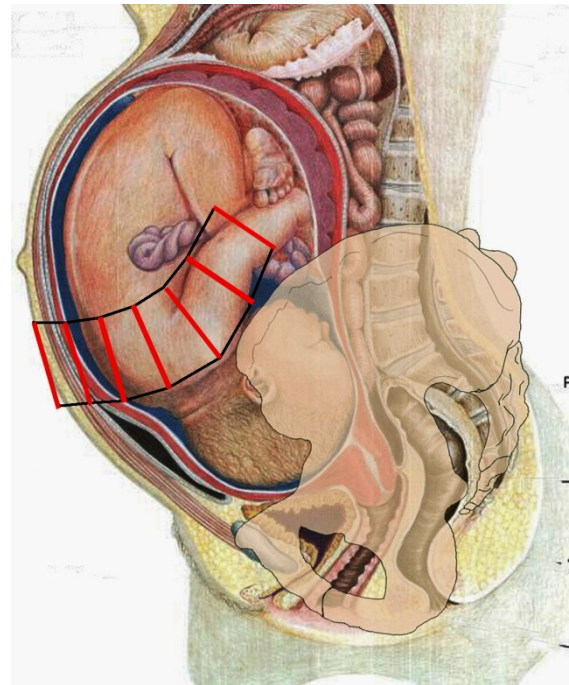




**Figure 8 Mechanism of Pelvic Submarining**

As the event progresses, the lap belt penetrates the abdomen and fetus as the legs continue to pull the lower pelvis forward. The head is also rotating forward in response to the crash acceleration and shoulder belt retention forces. In Frame 4 the lap belt has penetrated more than half way through the fetus' body, and the pelvis is on the verge of rotating under the belt. As the event proceeds to Frame 5, the lap belt has penetrated completely through the abdomen to the lumbar spine. The fetus is trapped between the horizontal lap belt and the vertical lumbar spine. This is commonly referred to as "submarining" or "porpoising" of the pelvis under the lap belt.

Figure 9 shows the approximate path of the lap belt through the uterus with full submarining.



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**Figure 9 Lap Belt Path, Full Term**

Eleven pregnant baboon test subjects were exposed to sled testing simulating automobile crashes. The results were reported in 1968 [8].

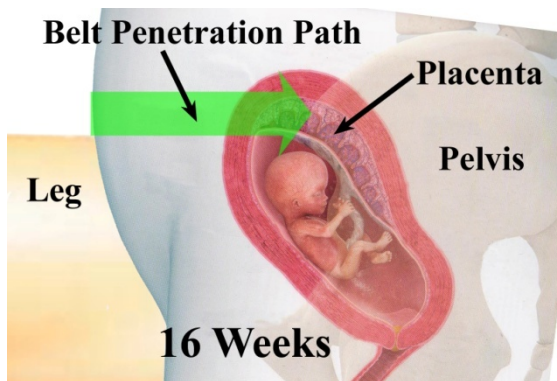
Principal conclusions of this study were, "...the lap belt should not be worn over the fundus", and "Pregnant women should wear lap belts to prevent ejection from the vehicle, but it should be securely placed across the pelvis and not over the fundus. The high rate of fetal and placental injury in this study indicates that additional restraint may necessary to reduce the snubbing action of the lap belt."

It is interesting to note that the National Highway Traffic Safety Administration has used Figure 10 to illustrate the "correct" position for the lap belt on a pregnant woman since the mid 1970's.



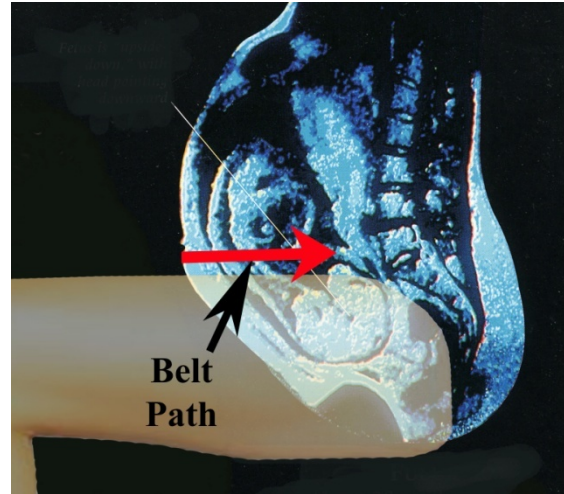
**Figure 10 NHTSA Recommended Lap Belt Position**

At 16 weeks, the fundus is directly under the NHTSA recommended lap belt location as shown in Figure 11. This is in direct contradiction of the above recommendations



**Figure 11. Belt Penetration Path - 16 Weeks.**

Later in the pregnancy the lap belt crosses the abdomen at the height of the fetus' spine, assuring that the fetus would be crushed between the mother's body and the belt in a frontal crash as shown in Figure 12.



**Figure 12 Belt Penetration Path – 3<sup>RD</sup> Trimester**

The fact is that it is not possible to position the lap belt in a way that would prevent crushing the fetus in a frontal crash. Clearly lap and shoulder belts alone are not appropriate for use by pregnant women.

## THE BIOMECHANICS OF AIR BAG RESTRAINTS

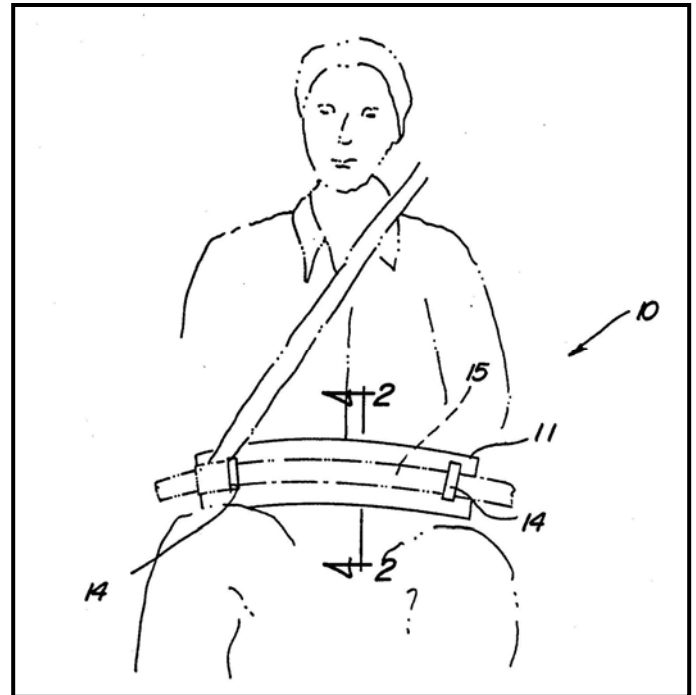
Most contemporary automobiles in the United States are equipped with a combination safety belt-air bag system with the belts designated as the primary restraint system. Depending on the specific geometry and air bag inflation characteristics, in a given case the air bag could help prevent submarining, reduce lap and shoulder belt loading, and limit distension and extrusion of the abdomen between the belts. It is not possible to generalize this possibility because of the variations in system design and seated geometry of specific cases.



## SUPPLEMENTARY PADS AND CUSHIONS FOR PREGNANT WOMEN

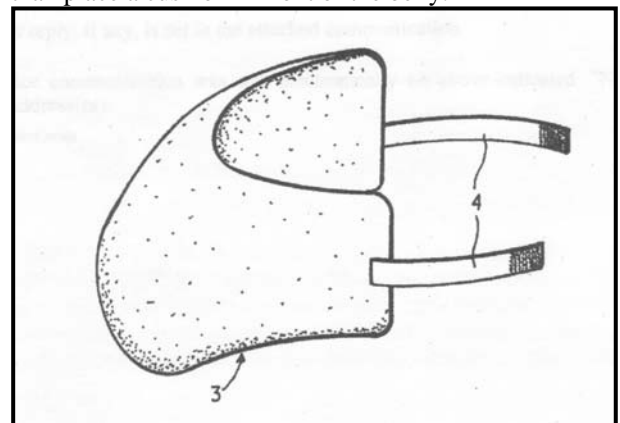
Several configurations have been identified for use by pregnant women that are basically intended to more broadly distribute belt forces over the surfaces of the abdomen and upper torso using a variety of supplemental pad(s) or cushion(s). Several of these configurations are shown in Figures 11, 12, and 13.

With the Lap Belt Pad shown in Figure 11 the lap belt is elevated relative to desired position of the belt as low as possible on top of the legs. This would raise the belt above the iliac crests. This would defeat the intended function of the lap belt, which is to apply restraining load as low as possible to engage the iliac crests. This device would do just the opposite by directing more of the lap belt load directly onto the surface of the abdomen just above the iliac crests. This elevation of the belt would greatly increase the tendency for the pelvis to submarine and the likelihood of abdominal injury. Since the lap belt pad must be stiff enough to distribute the belt load as intended, it would provide some protection from abdominal penetration by other objects, but it would create a major abdominal distortion point at the top edge of the pad.



**Figure 11 Lap Belt Pad (US 5213366)**

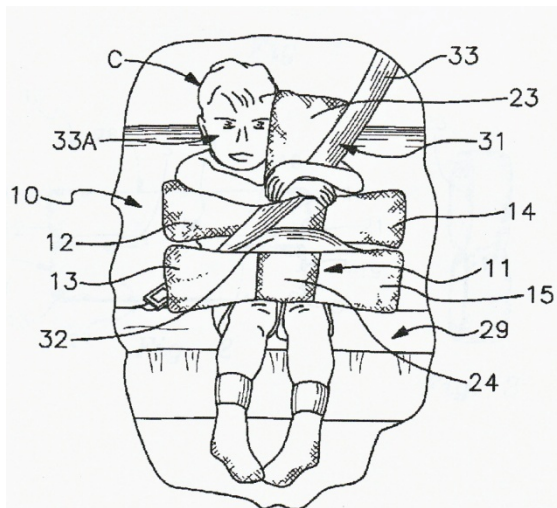
In the Belly Pad configuration Shown in Figure 12, it is not clear that the device does anything other than place a cushion in front of the belly.



**Figure 12. Belly Pad (US 3936075)**

The Multiple Cushion configuration shown in Figure 13 does not appear to have any merit from a crash injury point of view. It could improve the comfort of the passenger if the cushions were relatively soft, but to have any significant effect on crash injury, the cushions would need to be at least

semi rigid in order to better distribute belt forces. Such cushions would be very uncomfortable and restricting for a pregnant woman in the depicted configuration.

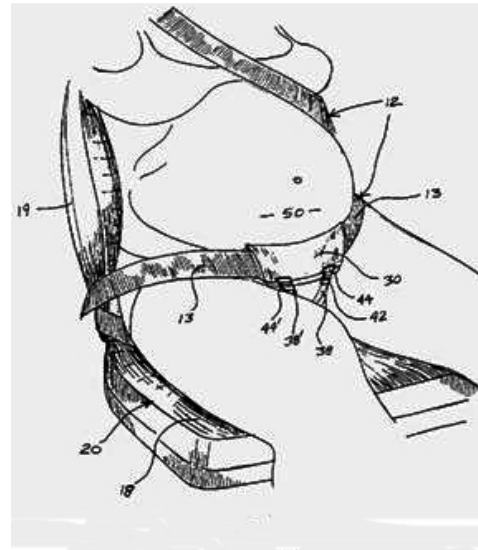


**Figure 13 Multiple Cushions (US 7086703 B1)**

The extent to which any of these devices would actually distribute belt forces more broadly would depend on the specific geometry and structural properties of the pads or cushions. At the least they should have rigid or semi-rigid properties to prevent the belts from penetrating through, and perhaps applying a more concentrated loading pattern than the belt itself. All of them would either have no effect or exacerbate the tendency of the pelvis to submarine and injure the lower abdomen.

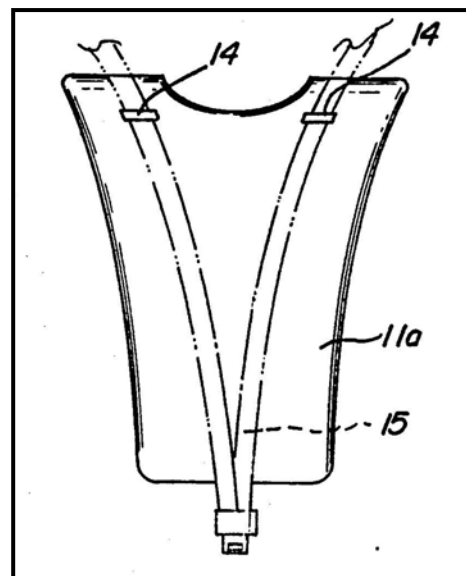
## CROTCH STRAPS FOR PREGNANT WOMEN

A crotch strap is a strap attached to the structure of the seat or vehicle, downward between the occupant's legs. Usually the top end of the strap is attached to the lap belt, but there are many variations. These devices are in common usage in competitive racing vehicles and various high risk military applications. The configurations shown in Figures 14 and 15 were both identified for use by pregnant women.



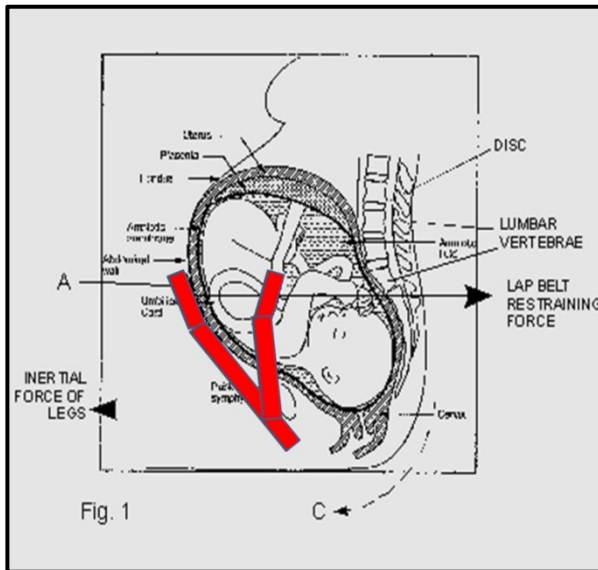
**Figure 14 Crotch Strap with Lap Belt (US 5005865)**

It should be noted that the configuration shown above would allow the lap belt to be pulled downward sufficiently to apply the needed force directly to the pubis without involving the lower abdomen. The configuration shown does not accomplish this, but it would be possible with a similar configuration. The junction plate shown in the illustration would need to be pulled all the way downward between the legs to the level of the seat cushion.



**Figure 15 Crotch Strap with Partial Shield (US 5213366-1)**

Crotch straps are highly effective in preventing submarining, but they still allow deep penetration of the lower abdomen by the belts during a crash as shown in Figure 16.



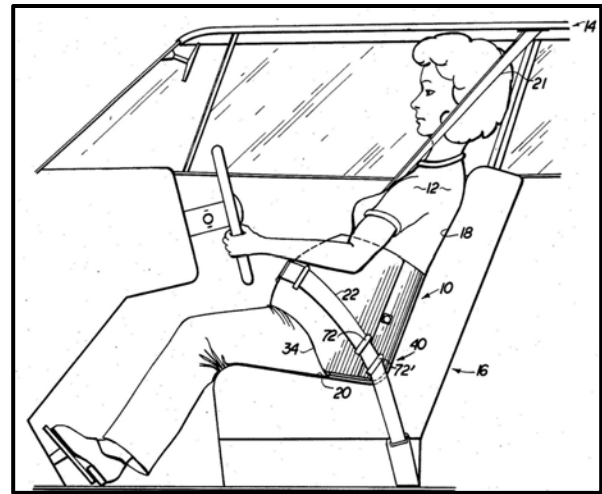
**Figure 16 Penetration of Crotch Strap and Lap Belt During Crash**

## ABDOMINAL SHELL CAPS FOR PREGNANT WOMEN

A third category of device has been identified for use by pregnant women that utilizes a shell over the abdomen to redistribute lap and shoulder belt forces, and prevent penetration by the belts and other objects. These devices are typically arched over the area required by the pregnant abdomen.

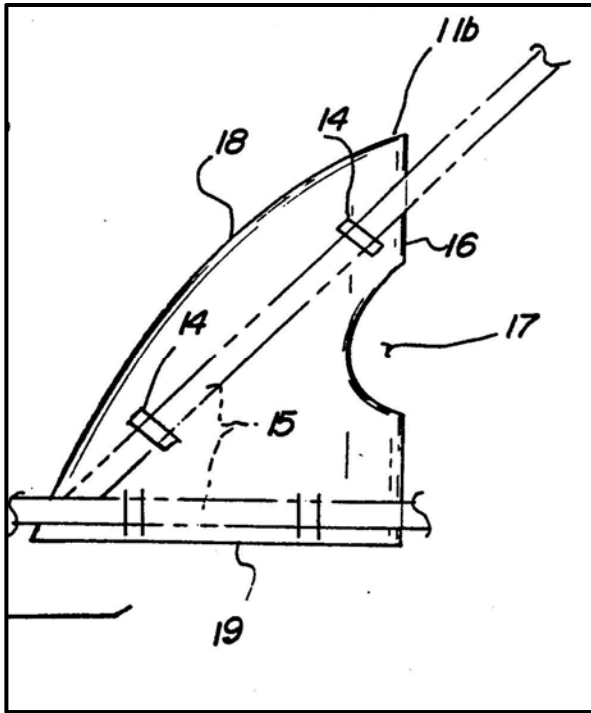
The half shell configuration as shown in Figure 17 holds the lap belt well above the tops of the legs and the iliac crests. In a frontal crash, this arrangement would defeat the purpose of the lap belt to apply loads directly to the iliac crests rather than to the abdomen itself. In addition, it would not only encourage submarining, but the shell would likely rotate bottom forward to virtually assure submarining. The top edge of the shell would be forced backward into the upper abdomen, the lower ribs, and the breasts. The top semi-sharp edge could cause injury to the upper abdomen, lower ribs and

breasts as the body submarines under the shell and belt.



**Figure 17 Half Shell (US 4610463)**

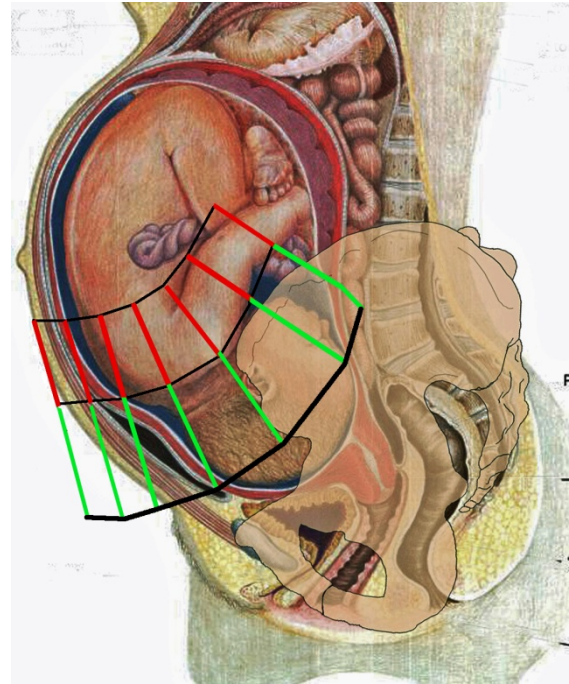
Figure 18 shows a Full Shell configuration, which suffers all of the same problems as the half shell except that the upper edge injuries are moved upward to the neck.



**Figure 18 Full Shell (US 5213366-2)**

These devices also introduce the likelihood of yet another side effect injury mechanism. Consider the effect the lower edge of the shell as the legs pull forward causing the pelvis to rotate bottom forward and submarine under the shell. The baby's head is locked in the pelvis during late term pregnancy, and anything below the lower edge of the lap belt that does not stabilize the pelvis by contacting the pubis would attempt to scoop through the head as shown in Figure 19.

The red objects trace the expected path of the lap belt as it penetrates the abdomen and moves over the pelvis. The black objects represent the expected path of any structure that extends below the belt, but does not engage the pubis and iliac crests. In the actual case, the pelvis would rotate as shown in Figure 8, and the scooping would extend deeper into the pelvic cavity than is shown.



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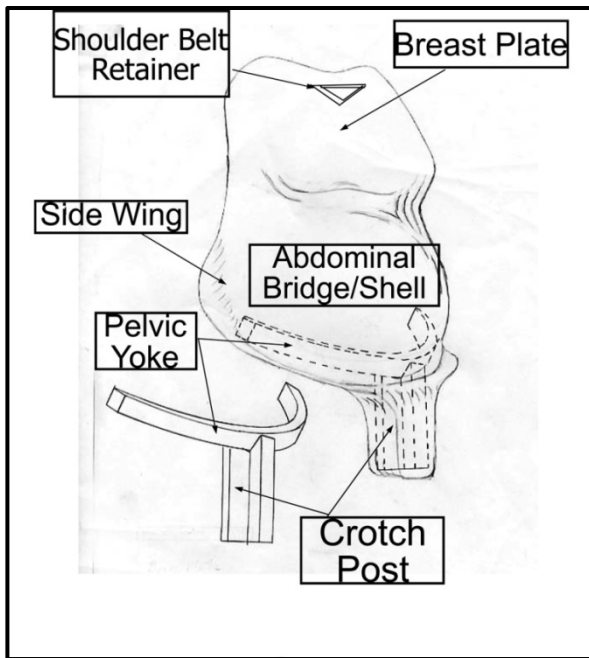
**Figure 19 Abdominal Scoop Injury**

This injury mechanism is referred to as abdominal scoop injury. These shell configurations that do not provide engagement of the pubis to stabilize the pelvis would be expected to produce this type of injury.

If submarining did not occur with these devices, the entire shell would penetrate straight back, displacing the uterus. In this situation the uterus and fetus would be ejected out under the bottom edge of the shell. Both of the partial shell configurations are potentially more dangerous to the fetus than the lap belt alone.

Figure 20 shows an Integrated Abdominal and Breast Isolation Shell which precludes submarining and isolates the entire abdomen from lap and shoulder belt forces. It also protects the abdomen from impact or penetration by other objects in the car, such as the steering wheel, air bags, dash board, and other objects. This is accomplished by covering the entire front of the breast, belly and crotch with a structural shell.





**Figure 20 Integrated Abdominal Bridge-Shell , Pelvic Yoke and Breast Plate (US 8070184 B2)**

The pelvic yoke and crotch post establish direct contact with the pelvic pubis and iliac crests to stabilize the pelvis and bridge over the pregnant lower abdomen. The top-aft rotational force components are transmitted through the abdominal bridge shell and reacted against the ribs.

The only interaction between the belly and the shell occurs during a crash when the shell restrains the belly and prevents it from distending forward. The forces required to prevent excessive forward distension of the belly are applied by the shell and distributed over the belly and transmitted to the pelvic yoke and breast plate, where they are reacted into the belts. These forces are caused by the inertial properties of abdomen and mid torso. They are reacted into the belts rather than being caused by the belts.

The forces required to restrain the portions of the woman's body above and below the belts are also reacted into the belts by the shell, but the abdomen and mid torso are isolated from these forces by the shell bridging structure.

Figure 21 shows a prototype model of an Integrated Abdominal and Breast Isolation Shell.

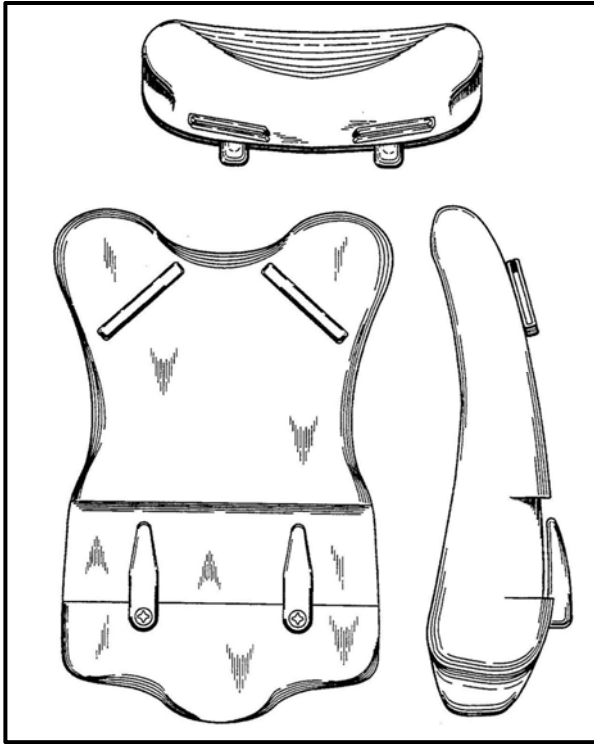


**Figure 21 Integrated Abdominal Isolator (US 8070184 B2)**

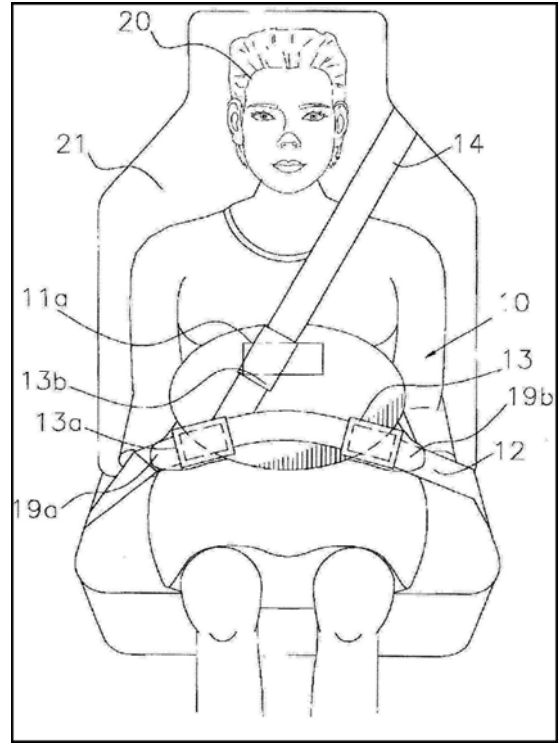
## OTHER RESTRAINTS IDENTIFIED FOR PREGNANT WOMEN

Several other restraint configurations that do not merit comment were identified by the USPTO as appropriate for use by pregnant women. Illustrations of some of these devices are shown below.

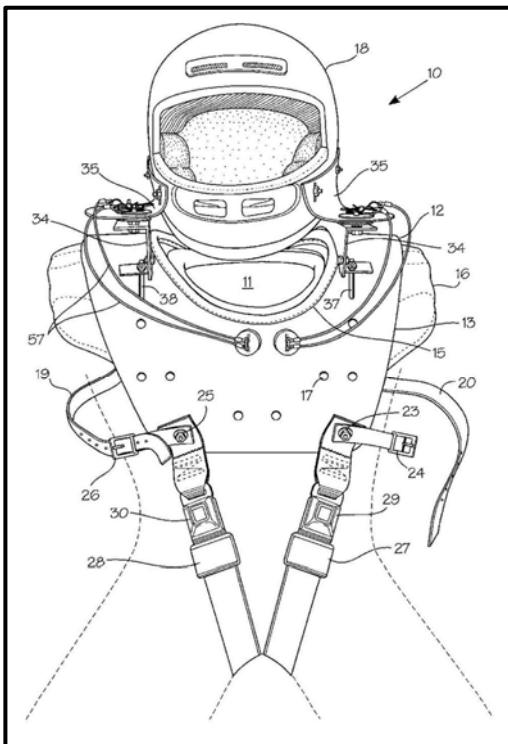




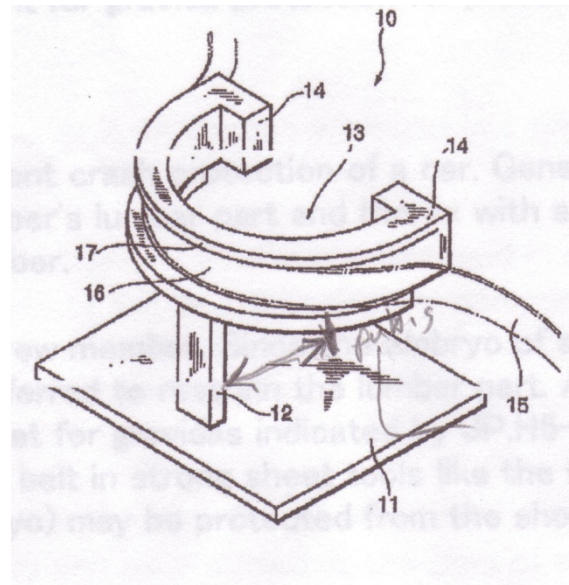
**Figure 22 Umpire Pad (US 349589)**



**Figure 24 Belly Cushion (US0052528 A1)**



**Figure 23 Dive Helmet (US 6,591,430 B1)**



**Figure 25 Gravid Protection (JP, H-40060, U)**

## CONCLUSIONS

1. Lap and shoulder belt restraints are not suitable for use by pregnant.
2. No testing method or protocol has been developed to credibly assess the performance of various devices and configurations regarding fetal safety in motor vehicle crashes.
3. Only 3 of the identified devices are both compatible with conventional seat belts and prevent pelvic submarining as follows.
4. Only 2 of these devices is consistent with the recommendations of the relevant biomechanics research [1,8 ].

Patent No.	Compatibility With Seat Belt	Prevents Pelvic Submarining	Consistent With Biomechanics Requirements	Isolates Abdominal	Prevents Abdominal Distortion
JP H-40060	+	+	-	-	-
US 5005865	+	+	+	-	-
US 8070184	+	+	+	+	+

## RECOMMENDATIONS

1. The Society of Automotive Engineers should undertake the development of a “SAE Recommended Practice” regarding fetal protection in motor vehicle crashes while the mother is using conventional lap and shoulder belt restraints.
2. The National Highway Traffic Safety Administration should update its recommended usage of the lap and shoulder belt by pregnant women to reflect the advice of the 1968 research conclusions [8] and this review of the

current technology relative to the restraint of pregnant women in motor vehicles.

3. The National Highway Traffic Safety Administration should initiate rulemaking to specify minimum required performance requirements for supplemental restraint systems for pregnant women.
4. The National Highway Safety Administration should initiate rulemaking requiring labeling of motor vehicles equipped with lap and shoulder belt restraint systems warning pregnant women that use of the lap and shoulder belts may injure or kill their unborn children, such labels to be similar to the current warning labels relating to child injury or death caused by air bags.
5. The National Highway Safety Administration should initiate rulemaking requiring that pregnant women riding in or driving motor vehicles equipped with lap and shoulder belts to use a supplementary restraint system certified for compliance with the newly established Federal Motor Vehicle Safety Standard specifying minimum performance requirements for supplementary restraint systems for pregnant women.

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## ACKNOWLEDGEMENTS

The author would like to thank Albert King and Mark Warner for their helpful comments and support.