Reducing Highway Deaths and Disabilities with Automatic Wireless Transmission of Serious Injury Probability Ratings from Vehicles in Crashes to EMS

ESV Paper 406

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Abstract – The National Highway traffic Safety Administration (NHTSA) developed software called URGENCY for use with Automatic Crash Notification (ACN) technologies to improve triage, transport, and treatment decision-making. The aim is to identify, instantly and automatically, the approximately 250,000 crashed vehicles with serious injuries occurring each year from the 28,000,000 crashed vehicles with minor or no injuries.

Introduction - The National Academy of Sciences issued a report in September 1966 that noted that “49,000 deaths in 1965 were due to motor-vehicle accidents.” That report, *Accidental Death and Disability: The Neglected Disease of Modern Society*, focused on emergency care noting that “Data are lacking on which to determine the number of individuals whose lives are lost or injuries are compounded by misguided attempts at rescue or first aid.” The title, the findings, and many of the recommendations in that 1966 report are applicable to this day 37 years and more than 1,700,000 deaths later [1].

One of the report’s recommendations was: “Active exploration of the feasibility of designating a single nationwide telephone number to summon an ambulance.” Thirty-three years later, the Wireless Communications and Public Safety Act of 1999, became law and specified 9-1-1 as the “universal emergency telephone number.” The Act, based in part on the research findings reported herein, states that “emerging technologies can be a critical component…to reduce emergency response times and provide appropriate care”.

The Act’s first finding states:

> “…the establishment and maintenance of an end-to-end communications infrastructure among members of the public, emergency safety, fire service and law enforcement officials, emergency dispatch providers, transportation officials, and hospital emergency and trauma care facilities will reduce response times for the delivery of emergency care, assist in delivering appropriate care, and thereby prevent fatalities, substantially reduce the severity and extent of injuries, reduce time lost from work, and save thousands of lives and billions of dollars”[2].

Also in 1999, the Federal Communications Commission (FCC) issued rules for Enhanced 9-1-1 service for wireless calls to automatically provide location information to emergency dispatchers.

The stimulus for research reported herein originated from findings at the William Lehman Injury Research Center (WLIRC) in the early 1990’s on occult injuries among occupants protected by air bags and/or belts [3]. The National Highway Traffic Safety Administration (NHTSA) subsequently initiated research to meet the need to provide more timely, and more informative, notification of serious injury crashes to the emergency medical care community to reduce deaths and disabilities. The NHTSA Office of Crashworthiness Research convened a multidisciplinary team of trauma surgeons, emergency physicians, crashworthiness engineers and statisticians under a cooperative research agreement with the University of Maryland National Study Center for Trauma and EMS. The purpose of the project was to improve triage, transport, and treatment of people injured in crashes. The team recommended use of Automatic Crash Notification (ACN) technology with *URGENCY* software to produce significant improvement in post-crash care with substantial benefits in reductions of deaths and disabilities from crash injuries. This recommendation has gained growing acceptance.

In 2002, several milestones marked advances toward widespread deployment of Automatic Crash Notification technology. The American College of Emergency Physicians (ACEP) adopted a resolution supporting “the development and implementation of programs, policies, legislation, and regulations that promote the use of Automatic Crash Notification (ACN).” [4] Subsequently, both GM and Ford announced deployments of advanced Automatic Crash Notification technology in fleets of their vehicles. GM OnStar announced that it would equip 400,000 vehicles beginning in 2003. [5] Ford announced a test fleet of 500 police vehicles to begin operating in Houston Texas in 2002. [6] The current NHTSA Administrator, Jeffrey W. Runge, MD, recently expressed his support for ACN technologies "Serious crashes happen every day, more than half of them in rural areas where the ability to rapidly contact 9-1-1 and the capability of responders to quickly reach the scene can mean the difference between life and death. New technologies such as wireless E9-1-1, automatic collision notification and emergency vehicle route navigation are available that will make emergency access more reliable and help deliver faster and better emergency care." [7]

Background – Beginning with its first Administrator, Dr. William Haddon, NHTSA has worked to improve the emergency treatment of crash victims. An early study funded by the agency, published in 1971, "Alcohol and Highway Safety: Behavioral and Medical Aspects" highlighted the need for improving emergency medical treatment of crash injuries. [8]

During the early 1990's NHTSA, while conducting hospital based research into the nature of crash injuries, observed cases that documented the need to improve triage, transport, and treatment decision-making. As the use of seat belts was increasing and more people were being protected by air bags, injury patterns were changing and injuries became more difficult to recognize. The chance of missing occult injuries was (and is) growing. Now there are more than 133 million vehicles on U.S. roads with air bags (more than 60 percent of the fleet). Belt use is also growing and has reached 75 percent in 2002. [9]

The agency discovered these new injury patterns in its trauma center studies, initially at the William Lehman Injury Research Center in Miami. Previously external injuries were an obvious indicator of crash severity and of the potential presence of internal injuries. However, the growing absence of external injuries among people protected by air bags and/or belts was now found to be misleading emergency medical care providers into missing internal injuries -- sometimes with fatal consequences. This resulted in NHTSA publishing a Research Note in 1993, and a Poster in 1994 titled "Look Beyond the Obvious" to educate the EMS community to the changing pattern of injuries. [3]

These findings were from studies conducted by the NHTSA Office of Crashworthiness Research into crashes, injuries, treatments, and outcomes. These crashworthiness studies became the model for research currently conducted under the NHTSA CIREN program at ten trauma centers in the U.S. [3, 10-14, 16-18]. In the early 1990's, NHTSA also funded three Rural Preventable Mortality Studies (Montana, Michigan and North Carolina) that found preventable death rates of 17%, 13% and 29% respectively. These, and more recent, studies documented a continuing need to improve emergency medical care for crash victims. [19-21, 65-69].

The Problem - The problem of motor vehicle crash injuries is one of substantial and continuing magnitude. NHTSA projects that "With yearly increases in travel and no improvement in safety over our current safety performance, fatalities could increase by 50 percent by 2020." [22].

Since 1900, in motor vehicle crashes along U.S. roadways, more than 3 million Americans have been killed, and 300 million injured. That is more than 3 times the number of Americans killed, and 200 times the number wounded in all wars since 1776. Worldwide, an estimated 30 million people have died from crash injuries.

In the U.S., the economic costs of crash injuries incurred each year amount to an estimated $140 billion. Including compensation values for pain and suffering, the comprehensive costs of crash injuries incurred each year amount to an estimated $345 billion [23]. The human costs to individuals and families of the deaths, injuries, and disabilities incurred in crashes, each year, are unmeasured tragic losses that burden our society – for decades.

Each year, along the 4 million miles of roads in the U.S., about 5 million Americans are injured in 17 million crashes involving 28 million vehicles. Among those 28 million crash-involved vehicles, approximately 250,000 Americans suffer life-threatening injuries. Specifically where and when they will occur is not predictable. Thus, it is important to be able to distinguish, instantly and automatically, the one (1) crashed vehicle that has a seriously injured person from every 100 vehicles in crashes, most of which have no injury or simply minor injuries [23-30].

ACN systems that combine information from vehicle crash sensors and global positioning technology, and transmit it to EMS via wireless address this challenge. The challenge is to improve the timeliness and quality of emergency response and care over present practices. [40, 56, 64] Currently in virtually all 42,000 deaths and 250,000 serious injuries every year, helicopter rescue operations do not begin unless, and until, someone travels over land to the crash scene. Consequently rescue is, too often, too late to save lives and prevent disabilities.

Methods: NHTSA Research - Members of the research team were brought together for their expertise in trauma care research, advanced technologies, emergency medicine, crash data analysis, and motor vehicle crashworthiness engineering. The team conducted retrospective analyses of NHTSA data on crashes, deaths, and injuries. The multidisciplinary team members directed, conducted, and reviewed a series of statistical analyses of NHTSA's FARS and NASS electronic crash data files. A series of meetings were held over a period of a year to conduct and refine the analyses, and to develop software that could be used to improve triage, transport, and treatment decision-making for future crash victims. Beginning in March 1997, the team presented its findings and recommendations to executives within the NHTSA. Then, they were presented to other organizations concerned with reducing morbidity and mortality of crash victims [26-30, 58, 60-63].

The focus of this research was "How to identify, rapidly and automatically, those vehicles in which people are seriously injured and need time-critical emergency care?" Findings from NHTSA-funded trauma center studies led to this question [3, 10-13, 17]. NHTSA statistics on crash deaths and injuries from FARS and NASS became the basis of this research for answers.

The approach involved reviewing the "mechanism of injury" criteria in current triage guidelines [33]. One objective was to review the current criteria by conducting statistical analyses of the body of crash injury data that had been created over the past decade in FARS and NASS. Such data were not available when the work supporting the current mechanism of injury triage guidelines were created more than a decade ago [13].

Another objective of this research was to develop crash injury probabilities associated with vehicle crash sensor measurements of crash severity for automatic crash notification software to improve triage, transport, and treatment. The team reviewed the scientific literature and conducted hundreds of statistical analyses of the NHTSA electronic files on fatal crashes and on injury crashes. Logistic regression analyses were used to relate injury probabilities to parameters of crash severity including Delta V and principal direction of force in the crash as estimated in NASS data. Then a mathematical algorithm was created to generate statistical probabilities of serious injury based on crash parameters. These relationships were incorporated in software named *URGENCY 1.0.* [30].

Table 1 shows NHTSA FARS data on motor vehicle related fatalities and whether or not the crash victims were transported to a medical treatment facility. About 42,000 Americans die from crash injuries each year. Nearly 20,000 people die each year before being taken to hospital for medical care. Before reaching a hospital, about 13,500 people die from injuries in crashes along rural roadways and about 6,500 in crashes along urban roadways. The remaining 22,000 people die either en route or after reaching hospital.

Figure 1 shows that in the year 2000, the number of people dying in crashes without being taken to a medical treatment facility amounted to 20,828 deaths, nearly 50 percent of crash deaths. The number of crash fatalities each year that are "Not Taken" to a medical treatment facility has not declined during the past 15 years. The number of crash fatalities "Taken" for medical treatment declined during the 1980's but that decline did not continue in the 1990's.

In this research, attempts to clearly quantify individual factors contributing to the changes in "Taken" and "Not Taken" over the decades were not completed. One factor, for example, changes in EMS over this period have resulted in greater authority of EMS to declare people dead at the scene. Many such crash fatalities 25 years ago were transported to a medical facility to be declared dead. Future research may be able to quantify factors contributing to the trends in national statistics during this period of time.

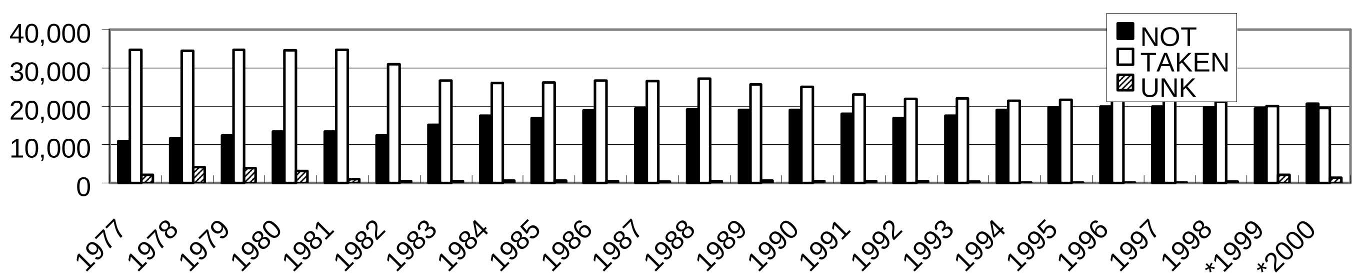
However, it is clear that many of the fatalities, "Taken" and "Not Taken" resulted from serious injuries that did not receive timely definitive medical care. Hopefully, in the future, improvements in triage, transport, and treatment, with ACN plus *URGENCY*, will reduce the number of deaths of people **--** both those "Taken for Treatment" and those "Not Taken for Treatment."

Table 1 DEATHS OF PEOPLE NOT TRANSPORTED, TRANSPORTED, AND UNKNOWN TRANSPORT TO A MEDICAL TREATMENT FACILITY

	RURAL			URBAN			UNKNOWN					TOTALS				
YEAR	NOT TAKEN	TAKEN	UNK	NOT TAKEN	TAKEN	UNK	NOT TAKEN	TAKEN	UNK	TOTAL	YEAR	NOT TAKEN	TAKEN	UNK	% Transported for Treatment	% Dead @ SCENE
1977	7,883	19,077	1,503	2,940	15,668	688	9	109	1	47,878	**1977**	10,832	34,854	2,192	73%	23%
1978	8,656	18,905	2,457	3,074	15,539	1,250	4	50	396	50,331	**1978**	11,734	34,494	4,103	69%	23%
1979	8,687	18,283	2,165	3,721	16,500	1,286	4	33	414	51,093	**1979**	12,412	34,816	3,865	68%	24%
1980	9,352	18,032	1,730	3,964	16,533	1,063	3	35	379	51,091	**1980**	13,319	34,600	3,172	68%	26%
1981	9,169	17,981	542	4,283	16,225	274	1	682	144	49,301	**1981**	13,453	34,888	960	71%	27%
1982	8,343	16,311	351	4,018	14,464	196	8	253	1	43,945	**1982**	12,369	31,028	548	71%	28%
1983	10,309	13,822	355	4,894	12,940	193	17	59		42,589	**1983**	15,220	26,821	548	63%	36%
1984	12,014	13,224	402	5,474	12,925	187	3	28		44,257	**1984**	17,491	26,177	589	59%	40%
1985	11,486	13,255	453	5,333	13,040	231	3	24		43,825	**1985**	16,822	26,319	684	60%	38%
1986	13,117	13,125	242	5,835	13,562	184	1	21		46,087	**1986**	18,953	26,708	426	58%	41%
1987	13,633	13,279	219	5,735	13,368	114	12	30		46,390	**1987**	19,380	26,677	333	58%	42%
1988	13,712	13,711	372	5,491	13,622	138	11	30		47,087	**1988**	19,214	27,363	510	58%	41%
1989	13,297	12,696	399	5,831	13,129	200	5	25		45,582	**1989**	19,133	25,850	599	57%	42%
1990	13,079	12,346	336	5,933	12,678	196	15	16		44,599	**1990**	19,027	25,040	532	56%	43%
1991	12,432	11,594	302	5,550	11,451	125	14	40		41,508	**1991**	17,996	23,085	427	56%	43%
1992	11,554	10,960	307	5,217	10,871	135	59	146	1	39,250	**1992**	16,830	21,977	443	56%	43%
1993	12,019	11,155	285	5,499	10,813	117	94	155	13	40,150	**1993**	17,612	22,123	415	55%	44%
1994	12,854	10,852	135	6,135	10,579	97	30	34		40,716	**1994**	19,019	21,465	232	53%	47%
1995	13,089	10,799	109	6,326	10,572	87	397	435	3	41,817	**1995**	19,812	21,806	199	52%	47%
1996	13,388	11,030	92	6,441	10,722	81	49	103	1	41,907	**1996**	19,878	21,855	174	52%	47%
1997	13,691	11,322	122	6,281	10,450	98	23	26	0	42,013	**1997**	19,995	21,798	220	52%	48%
1998	13,683	11,199	209	6,042	9,901	158	96	167	16	41,471	**1998**	19,821	21,267	383	51%	48%
***1999**	13,383	10,824	1,341	5,940	9,256	862	48	53	10	41,717	***1999**	19,371	20,133	2,213	**48%**	46%
***2000**	13,789	9,921	814	6,466	8,982	499	573	676	101	41,821	***2000**	20,828	19,579	1,414	**47%**	50%
	282,619	***323,703***	***15,242***	***126,423***	***303,790***	***8,459***	***1,479***	***3,230***	***1,480***	***1,066,425***	*Totals*	***410,521***	***630,723***	***25,181***		

*** Unknowns in these years of FARS include "Died En Route" and "Not Dead at Scene and Not Taken (or do not go) to a Medical Treatment Facility"**

Fig. 1 DEATHS OF PEOPLE NOT TRANSPORTED, TRANSPORTED, AND UNKNOWN TRANSPORT TO AN INJURY TREATMENT FACILITY



Since 1977, more than 1 million people have died from crash injuries along U.S. roads. More than 400,000 of these people died from crash injuries without having been taken to a medical treatment facility. That represents the mortality part of the problem.

The morbidity part of the problem involves an estimated 250,000 Americans suffering seriously life-threatening injuries in crashes each year, many of whom could benefit from faster, more informed, treatment [23-25].

The most disabling injury which is compatible with life, but which produces the greatest degree of long term morbidity and cost is the posttraumatic brain injury. Recent studies have shown that there is a significant interaction between the initial severity of the brain injury and the degree and extent of duration of a period of hemorrhagic shock induced by blood loss. Even a mild to moderately brain injured patient is likely to have the severity of his or her cerebral damage accelerated by any period of continuing uncontrolled blood loss which increases the body's degree of oxygen debt. Thus, the shorter the time period in which the possible occurrence of a severe crash induced multiple trauma can be recognized, and the rapidity in which the correct EMS advanced life support team is dispatched, is likely to make the difference between a permanently disabling, or fatal brain injury, and a recoverable normal life. [67, 68]

The team's reviews of the current triage guidelines found that the application of new technologies offered the most promise for substantially improving upon the mechanism of injury criteria. Technologies were found to be available to provide:

(1) Automatic Crash Notification (ACN) via instant wireless communications of voice and data,

(2) Crash location information with Global Positioning System (GPS) and/or wireless network location technologies,

(3) Crash severity information measured by vehicle crash sensors.

The combination of these technologies on-board vehicles is termed Automatic Crash Notification (ACN). However, to make ACN medically useful, software was needed to translate crash sensor measurements of accelerations, direction of crash forces, and crash configuration into an easily understandable rating of crash severity for emergency medical dispatch.

Thus, the team examined NHTSA data with regard to how these technologies could improve outcomes by providing faster, and better informed, emergency medical response to crash victims. First, the team reviewed NHTSA data on fatal crashes as related to times recorded in FARS files to determine the magnitude of the problem. Second, the team focused on identifying the probability of serious (AIS 3+) injuries being present in a crash based on the relationships of crash severity data and injury incidences in NASS files. Third, the team developed software to convert the crash severity data from vehicle sensors into an easily understandable, objective, and actionable urgency rating that could provide EMS dispatchers with a probability rating of the presence of serious injuries. The software was named *URGENCY* 1.0 [26-30, 61, 62].

The literature of emergency medical care has long documented that for many serious injuries, time is critical. As described by RD Stewart:

> "Trauma is a time-dependent disease. 'The Golden Hour' of trauma care is a concept that emphasizes this time dependency. That is in polytrauma (*typically serious crash victims suffer multiple injuries*) patients, the first hour of care is crucial, and the patient must come under restorative care during that first hour.... Pre-hospital immediate care seeks to apply supportive measures, and it must do so quickly, within what has been called the 'Golden Ten Minutes.'" [35]

The team compared the available data on fatal crashes with the goal of trauma care to get seriously injured patients into a trauma center for diagnosis, critical care and appropriate surgical treatment within the "Golden Hour" [36-40]. The team used the following time intervals of data available in FARS on the delivery of patients to definitive care within the "Golden Hour":

(1) Time between crash occurrence and EMS Notification

(2) EMS Notification Time to EMS Scene Arrival

(3) EMS Time On Scene + Transport to Hospital

(4) Total Time from Crash to Hospital Arrival

(5) Recommended Time for Emergency Department Resuscitation (No Data in FARS)

Team members addressed new technologies that create opportunities in each category to act more rapidly and effectively to transport patients to obtain definitive care within the "Golden Hour."

Urban/Rural -- NHTSA FARS statistics on urban and rural fatalities generally are based on roadway function class. The statistics in this paper are also based on roadway function class.

A word of caution: use of the "Roadway Function Class" categorization of urban and rural results in classification of "rural" fatalities as fatalities that occur on rural roads in both rural counties and urban counties. An analysis that defined rural counties as having a population of less than 50,000 found that in 1998, there were 12,215 fatalities (29%) in rural counties and 29,256 fatalities (71%) on all roads in urban counties defined as having a population greater than 50,000.

The need and the opportunities are especially important on rural roads (in both rural and urban counties) where nearly 25,000 crash fatalities occur each year. Data collected by NHTSA show that only 24 percent of crashes occur on rural roads, but nearly 59 percent of the crash deaths occur on rural roads. "Delay in delivering emergency medical services is one of the factors contributing to the disproportionately high fatality rate for rural crash victims." [41]

Currently, each year, about 20,000 people die at the crash scene. The problem is greater on rural roads than on urban roads. Although for crashes on both rural and urban roads the number of deaths of people ***taken*** to a hospital for treatment is about equal at 10,000 per year, the number ***not taken*** on rural roads (13,500) is more than twice the number on urban roads (6,000).

On both urban and rural roads, about 16,000 (43%) fatal crashes occur each year between the hours of 9:00pm and 9:00am, times when crash discovery, notification, and emergency response are more likely to be slower.

Table 2 lists the ***average*** time intervals experienced in fatal crashes in the U.S. in 1998 [42]. Entry number 5 for the Emergency Department Resuscitation time interval is not based on FARS data, but rather is a medically recommended value of 15 minutes assumed for the purpose of relating pre-hospital times to the "Golden Hour" for the delivery of definitive care to save seriously injured patients [38].

Table 2. Average Elapsed Times in Fatal Crashes in 1998 (Minutes)

Time Intervals	***Urban***	***% Unknown***	***Rural***	***% Unknown***
1. Crash to EMS Notification	**3.6**	46	**6.8**	37
2. EMS Notification to Scene Arrival	6.3	47	**11.4**	35
3. Scene Arrival to Hospital Arrival	26.6	72	36.3	67
4. Crash to Hospital Arrival	35.5	71	**51.8**	68
5. Recommended Time for ED Resuscitation (No Data in FARS)	*15*		*15*	
Average Totals	51		**67**	

Notes:

- *These are U.S. average elapsed times that consist of shorter and longer times and vary greatly by State.*
- *Time intervals 2 & 3 do not include the elapsed time from crash to EMS Notification.*
- *Bolded times in Table 2 indicate average elapsed times that exceed benchmarks of **1 minute** for EMS Notification, **10 minutes** for EMS Scene Arrival, and **45 minutes** for Hospital Arrival in fatal crashes.*

Table 3. Crash Fatalities by Reported EMS Times (1998)

Time Intervals		*Fatalities*	*% of Time Interval*
Crash to EMS Notification:	<1 min.	9,195	*22%*
	>1 min.	**15,852**	*38%*
	Unknown + Questionable Times	16,424	*40%*
Crash to EMS Arrival at Scene:	<10 min.	12,161	*29%*
	>10 min.	**14,362**	*35%*
	Unknown + Questionable Times	14,948	*36%*
Crash to Hospital Arrival:	<45 min.	5,211	*13%*
	>45 min.	**3,166**	*8%*
	Not Taken + Unknown + Questionable Times	33,094	*79%*

Notes:

- *Bolded times in Table 3 indicate fatalities in which reported elapsed times exceeded benchmarks of **1 minute** for EMS Notification, **10 minutes** for EMS Scene Arrival, and **45 minutes** for Hospital Arrival in fatal crashes.*
- *Fatalities in each time interval equal 41,471 (100%) and fatalities may not be summed across time intervals.*

Table 3 lists the number of crash fatalities in 1998 with reported times that meet or exceed the benchmark time intervals, as well as the number reported as Unknown times, or Questionable times. The data in **Table 3** indicate the magnitude of the need for improvement in the rescue of crash victims.

Elapsed Time from Crash to EMS Notification:

Among crashes with reported times, nearly 4,000 fatalities occurred in 1998 in which more than 10 minutes elapsed before EMS was notified, much less able to deliver pre-hospital emergency care within the "Golden Ten Minutes." In addition, there were 14,708 crash fatalities (35%) where both times were not reported. With many of these fatalities, this time interval also may have exceeded ten minutes [24].

FARS data show that since 1992, there has been a steady reduction in the national ***average*** of both rural and urban fatal crash notification times -- down nearly 30% to 3.6 minutes on urban roadways and to 6.8 minutes on rural roadways in 1998.

This improvement in Crash to EMS Notification Times has been coincident with, and apparently significantly caused by, the increasing number and use of wireless telephones by crash-involved victims and "Good Samaritans." The number of wireless subscribers in the U.S. has grown from 5 million in 1990 to 128 million in 2001. The estimated number of wireless 9-1-1 distress calls over the same period has grown from 6 million to 57 million calls per year.

Note, however, that despite the increasing use of wireless phones, comparable percentage improvements have not been observed in the subsequent critical EMS time intervals discussed below [24].

In the future, with ACN, one can expect reductions in many of the longer times. With fully deployed ACN, ***all*** crash notification times, not just ***average*** notification time, will be reduced to about one minute. ACN has now demonstrated the technological and economical feasibility of a national EMS crash notification benchmark of 1 minute. [60]

Reductions in ***average*** crash notification times from 9 minutes to 1 minute after the crash have been estimated to potentially save 3,000 lives per year among crashes along rural roads [43]. When ***all*** crash notification times are reduced to 1 minute, the number of lives saved can be expected to be greater.

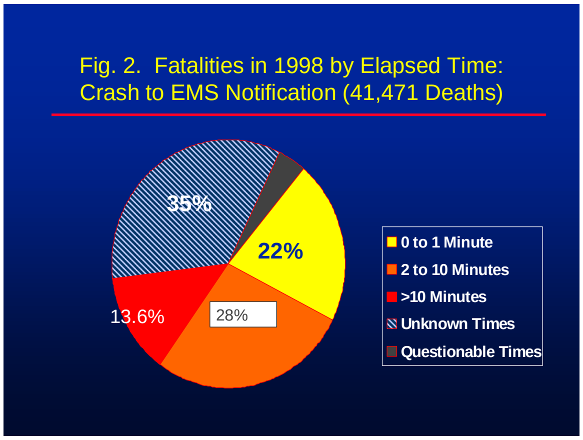


Figure 2. FARS data indicate that improvement in the system is still needed to get all EMS Notification Times down to 1 minute. In 1998, only 22 percent of all fatalities were reported to have EMS Notification within 1 minute of the crash. (In FARS files there are some questionable times e.g., where crash time appears to be later than EMS times. Such cases have not been included in the elapsed time segments.)

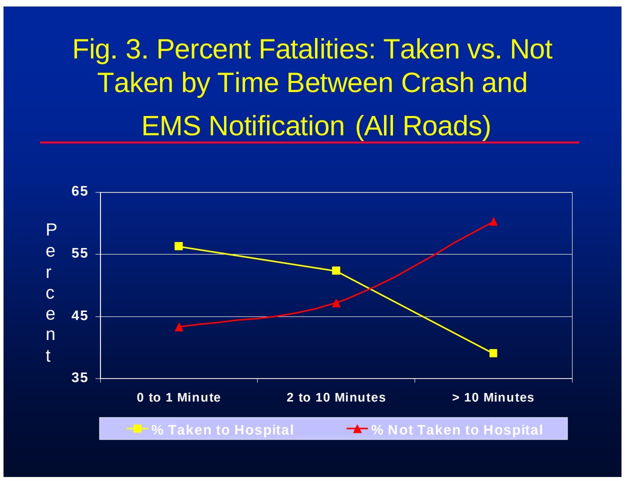
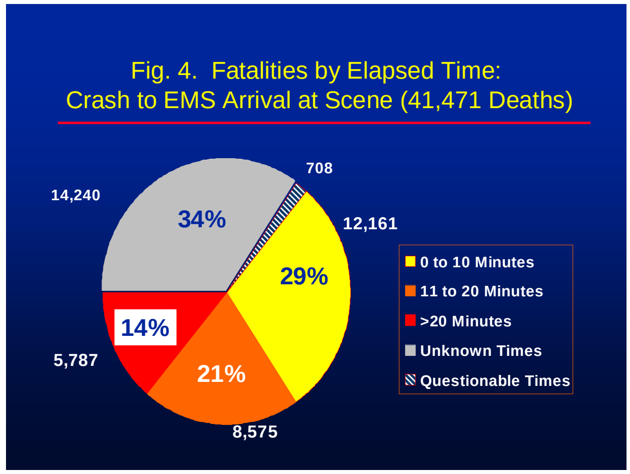


Figure 3 shows that increased times between crash and EMS Notification are associated with higher percentages of crash victims dying at the scene rather than being taken to a medical treatment facility. This effect of time between crash and EMS notification also is evident when multiple years of data are analyzed.

Elapsed Time from Crash to EMS Arrival at the Scene:

As shown in **Figure 4**, FARS data indicate how much further improvement in the system is still needed to get all fatal EMS scene arrival times to within 10 minutes. Among crashes with both reported times in 1998, there were 12,161 crash fatalities (29% of 41,471 deaths) in which the time from crash to EMS arrival was reported to be less than 10 minutes (14,240 unknown). There were 14,362 crash fatalities (35%), however, in which the reported time from crash to EMS arrival exceeded the "Golden 10 Minutes" (11,626 rural, 2,660 urban, and 76 unknown roadway classification). The actual number is higher, but unknown due to the large number of fatalities (14,240 or 34%) with unknown data on times, plus the 708 fatalities where the times were questionable.



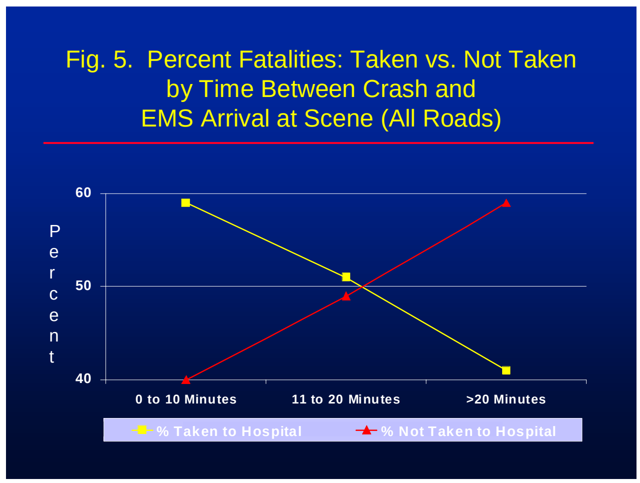


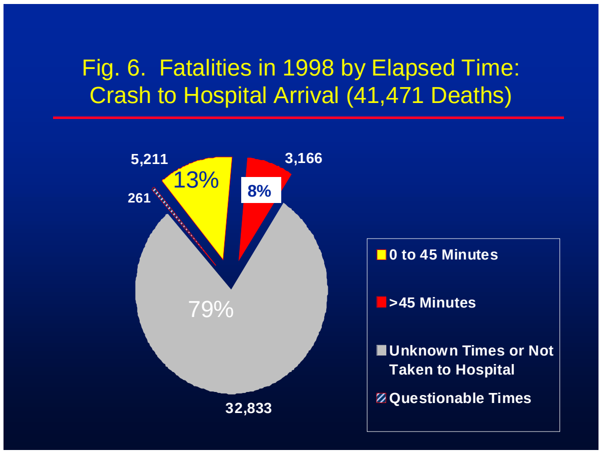
Figure 5 shows that increased times between crash and EMS arrival at the scene also are associated with higher percentages of crash victims dying at the scene rather than being taken to a medical treatment facility.

These data support the need for EMS arrival at the scene of serious injury crashes within the "Golden 10 Minutes."

In the future, with ACN, *URGENCY*, crash location information, automatic vehicle location and navigation equipment on board rescue vehicles, we can expect reductions in this time interval between crash and EMS Scene Arrival.

Elapsed Pre-hospital Times - Time of Crash to Hospital Arrival:

Figure 6 indicates how much improvement is needed to get crash victims to definitive care within the "Golden Hour." Nationwide, FARS data (where both times are reported) show that in 1998, there were 5,211 crash fatalities (13%) that were taken to a medical treatment facility within 45 minutes. In 1998, there were 3,166 fatalities (8%) in which the reported time from crash to hospital (not necessarily Trauma Center) arrival, exceeded 45 minutes. The actual number is probably much greater considering that for 33,094 crash fatalities (79% of all crash deaths), times were reported as unknown, questionable, or the victim was not taken to hospital for treatment.



Reducing Elapsed Time from EMS Arrival at Scene to EMS Arrival at Hospital:

ACN with *URGENCY* information will help dispatchers, instantly and automatically, decide to send appropriate resources such as extrication equipment in severe crashes, thereby, saving additional precious minutes in this time interval. In 1998, extrication was reported in crashes that resulted in 6,159 fatalities. Extrication is an increasingly important factor in fatal crashes. From 1990, when 4,426 fatalities occurred (in 12% of fatal crashes), it has grown to 7,051 fatalities involved in 19% of the fatal crashes in 2001. With ACN, it is now technically possible for rescue teams to have extrication information on the number of air bags, their location, and vehicle cut points specifically for the crashed vehicle - before arriving at the scene. Such time saving and lifesaving information could be included in the vehicle's ACN *URGENCY* data transmission.

In the future, ACN with *URGENCY* information will help produce instantaneous dispatch of appropriate resources (e.g. extrication equipment, ALS, helicopters). Navigation technologies also will help increase the number of people in potentially fatal crashes who get to hospitals and trauma centers within 45 minutes.

Emergency Department Resuscitation Times:

Current medical references allocate 15 minutes to Emergency Department (ED) resuscitation times for tests, diagnoses, decision making on treatment strategies, and required pre-operating room procedures before surgical care [38]. In **Table 2** the needed 15 minutes for ED resuscitation are added to the average reported times [42]. The result is that on rural roads with the 52 minutes that it currently takes to get a seriously injured patient to a hospital (often not a trauma center) in the average fatal crash, the "Golden Hour" is lost. Currently, in thousands of fatal crashes each year, victims do not obtain definitive care within the "Golden Hour".

In the future, *URGENCY* information on injury probabilities that are transmitted ahead to the hospital at the time of crash may include data on pre-existing medical conditions, blood types, drug reactions, and medications that will help reduce time currently lost in this time interval.

New Technologies **--** Automatic Crash Notification (ACN) technologies using crash sensors, GPS, and wireless telephones are now being installed on a growing number of production cars. Automobile manufacturers including Audi, BMW, Daimler Chrysler, Ford, GM, Honda, Land Rover, Nissan, and Toyota are offering first generation versions of ACN technology in the U.S. in 2002. These commercially available ACN systems report when an air bag deploys, but do not report measurements of crash forces in all crash modes.

In a field operational test from 1997 through 2000, the U.S. Department of Transportation (DOT), installed a more advanced version of ACN technology in 700 vehicles driven in the Buffalo, New York area. This ACN system, built by Veridian/Calspan Corp. for DOT, measured crash forces in all types of crashes (not just air bag deployment crashes) and automatically transmitted such data for instant conversion into *URGENCY* serious injury probabilities for EMS [26-30, 57-58, 60-61].

The DOT contract with the Veridian/Calspan Corp. of Buffalo, N. Y., was for the development and test of this advanced ACN technology. This ACN technology provided for an automatic, crash-activated, call for help using an on-board cellular telephone to transmit voice and data. The call electronically communicated information on the location of the crash and the severity of the crash (for all major crash modes: frontal, side, rear impacts, and rollover). It also transmitted data on vehicle pre-crash speed, direction of travel, and vehicle identification information including many attributes such as vehicle type. The equipment also opened a communication link to the vehicle occupants.

Of particular note, during this field operational test most crashes occurred in urban or suburban locations in western New York. Nevertheless, the ACN system was shown to reduce the average crash notification time by 4.5 minutes to less than 1 minute in 90 percent of the crashes. [60]

Results: URGENCY Information - In March of 1997, for the first time, the NHTSA funded research team developed *URGENCY* version 1.0 computer software to improve triage, transport and treatment decision-making using crash recorder data. The goal was to develop a system that instantly, and automatically, could help identify the approximately 250,000 vehicles in crashes involving serious injuries from among the approximately 28 million vehicles in crashes each year that are mostly fender benders. The *URGENCY* triage algorithm was developed by the team to predict serious injury probabilities based on vehicle, occupant, and crash parameters. All parameters, for which data was available, were evaluated in terms of their power to predict the probability of serious (AIS 3+) injury. The details of the URGENCY algorithm are contained in reference [30]. *URGENCY* version 1.0 is also available for interactive queries at http://www.comcare.org.

With *URGENCY* software, upon vehicle impact, crash sensor measurements are instantly, and automatically, translated into a single figure rating of urgency from 0 to 100%. This easy-to-understand rating provides the probability of a serious injury being present in that crash based on crash sensor measurements as related to the nation's statistical crash data on crashes and injuries.

Future versions of *URGENCY* software will employ additional sensor data to create a more robust and sophisticated triage, transport, and treatment decision-making tool. Future *URGENCY* ratings may calculate the probabilities of the presence of minor as well as major injuries. Information will be included such as the number, size and seating positions of occupants, seat track location (closeness to air bag), crash pulse, air bag time of deployment, level of air bag deployment, deployment of seat belt emergency tensioning retractors, seat belt forces, door openings, presence or absence of fire, pre-crash speed, and braking deceleration.

Findings -- The outcome of serious crash injuries is dependent, in part, on the timeliness, appropriateness, and efficacy of the medical care received by the crash victim. In too many cases, especially in rural areas, people die without having obtained definitive care at a trauma center within the "Golden Hour." Definitive care for seriously injured crash victims includes thorough, timely, and accurate diagnoses, intensive critical care facilities and staff, and readily available trauma teams with surgeons specializing in brain and spinal cord injuries, internal organ injuries, and orthopedic injuries, as required.

Notification times and response times will be improved with ACN and *URGENCY* software. Helicopter and other emergency response vehicles will reach the scene faster with on-board navigation systems using ACN crash location coordinates. Rescuers also increasingly will have on-board navigation guidance to the scene and to the appropriate treatment facilities via the "fastest route." With instant *URGENCY* information on the probability of serious crash injuries, one can expect EMS to do a better job of saving lives and preventing disabilities by taking people to the right place, faster. [26-30, 39-40, 60-62]

URGENCY software enables the nation to advance beyond current rescue practices - especially regarding helicopter dispatch [40, 56, 64]. In general, under current practices, when a crash occurs - however serious it may be - someone in authority (police, fire or EMS) first, must travel over land to the scene; second, make a determination that the seriousness requires a helicopter response; and third, send a radio request for air medical assistance. And if, and when, the request is granted, only then does the process of helicopter deployment begin. In the future, *URGENCY* computer assisted dispatch protocols will be developed to expedite this process -- with lifesaving results.

Benefits – Although benefits were not estimated in this research project, several projections of benefits by other researchers estimate that thousands of lives could be saved each year. In an independent evaluation of the DOT Field Operational Test of ACN equipped vehicles, published by DOT, researchers at the Johns Hopkins Applied Physics Laboratory estimated that "the ACN system could offer an approximate 20% reduction in fatalities" [61]. There also is a study, cited by the U.S. DOT, projecting that benefits of an ACN system (without *URGENCY*) could result in a 12% reduction in rural crash deaths and save an estimated 3,000 lives each year when average rural crash notification times are reduced to 1 minute [43]. Another study estimated benefits to range between 1.5 and 6 percent reduction in fatalities saving as many as 1,674 lives each year [46]. In addition to lives saved, it is reasonable to expect significant reductions in disabilities and human misery through the faster and more intelligent delivery of emergency medical care for non-fatal, but serious, injury crashes [48].

Significant benefits of ACN with *URGENCY* will also result in the long term from the data generated on crashes, injuries, treatments and outcomes. This data will form the scientific basis for continuous improvements in vehicles, roadways, driver behavior, and emergency care. Programs in crash injury prevention and treatment will have a new scientific resource for advancing safety.

Costs – GM has offered its OnStar system free for the first year and for $199.00 per year subscription cost in subsequent years. The OnStar system currently provides air bag deployment crash notification to a private call center. The OnStar center then calls for public "911" rescue service. OnStar currently is limited to only those crashes in which an air bag deploys (primarily frontal crashes, not rollovers, side, and rear impacts). Audi, BMW, Ford, Honda, Land Rover, Mercedes, and Toyota also offer similar airbag deployment crash notification systems on luxury model vehicles. In 2002, an estimated 3 million vehicles will be on US roads equipped with automatic (air bag deployment) crash notification systems.

The cost of the more advanced ACN safety equipment provided by Veridian/Calspan that covers all crash modes, according to Veridian/Calspan and the government, is estimated "at between $200 and $300" [50]. Moreover, the cost of electronics equipment is dropping fast as the technologies (and competition) develop and production volume increases. [51] The DOT Veridian/Calspan ACN technology also may be retrofitted into all cars, not just new cars, in the U.S. as a valuable safety feature. Operating costs are not included.

***Increasing Demand* --** The ability to make instantaneous wireless calls for emergency help (with automatic location) has been strongly identified in market research, both by the auto industry and the cellular industry, as products and services the public is willing to pay for as consumers. One series of market research studies found that the percent of new car buyers that said that Automatic Dial 911 Safety equipment is "important" or "very important" in their purchase decisions has been growing (48% in 1997, 53% in 1998, and 60% in 1999) [49]. More recently, a Louis Harris poll for Advocates for Auto and Highway Safety found 68% would like to have such safety equipment in their car [31].

In America, a group of trauma physicians, nurses, and others have joined with wireless communications companies to create the ComCARE (Communications for Coordinated Assistance and Response to Emergencies) Alliance to advance deployment of ACN. [32].

The National Academy of Sciences, in Reducing the Burden of Injury, noted the need to save people suffering from serious, time-critical, injuries. Whether time-critical injuries are the result of crashes or other causes, the timely delivery of optimal emergency care will help save lives and livelihoods. In addition, an advanced trauma care system will also result in saving the lives of people suffering from time-critical illnesses, such as strokes and heart attacks, needing rapid emergency medical transport and care [53].

A second recent National Academy of Sciences report, To Err is Human: Building a Safer Health System, notes "Preventing errors means designing the health care system at all levels to make it safer." This report recognized the importance of improving access to accurate, timely information in creating safety systems in health care [54]. With ACN, we now can provide objective, actionable, information to emergency medical system personnel instantly. These technologies can help us reduce the nation's burden of mortality and morbidity from crash injuries. The right information, at the right time will help reduce errors in emergency medical care.

A third recent National Academy of Sciences report, Crossing the Quality Chasm: A New Health System for the 21st Century, calls attention to the great potential of Information Technology to improve medical care. The report notes "A growing body of evidence supports the conclusion that various types of IT applications lead to improvements in safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity." [55, 65, 66]

***Conclusions* --** The technology is now available for an integrated, intelligent transportation system that delivers help wherever and whenever Americans are in danger, whether from crashes, crime, heart attacks, or other time-critical emergencies - in time to save lives. It is now technologically possible, and economically feasible, to have EMS crash notification within 1 minute, EMS scene arrival within 10 minutes, and trauma center arrival within 45 minutes of the crash in many of the 250,000 serious injury crashes occurring each year. The lifesaving and disability-reducing results will help build a safer America.

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