Use of an automatic crash notification system to relate dynamic vehicle data with occupant injuries

Anthony J. Billittier IV, MD
E. Brooke Lerner, PhD
Alan Blatt, MS
Michael Viksjo, MD

ABSTRACT
The objective of this study was to describe our initial experience with an automatic crash notification device (ACND) and to compare dynamic vehicle data acquired by the ACND in motor vehicle crashes (MVCs) for occupants with and without cervical strain injuries. Eight hundred and seventy-four cars were equipped with an ACND, which detected crashes by analyzing vehicular acceleration in real time. The device placed an automated call to 9-1-1 whenever the pre-established crash threshold was exceeded and transmitted crash location, principal direction of crash force, and crash change in velocity. All occupants involved in an MVC involving an ACND-equipped vehicle were contacted and asked to report anatomical location(s) of any injuries. Those with cervical-strain-type complaints were identified through post-crash interviews and medical record reviews. Principle direction of force and crash change in velocity were compared between these two groups. Dynamic vehicle data were obtained for 15 crashes involving 26 occupants, with crash change in velocity ranging from 12 kph to 42 kph. The principle direction of force was 12 o’clock (six vehicles), 2 o’clock (three vehicles), 3 o’clock (two vehicles), 6 o’clock (one vehicle), 9 o’clock (one vehicle), and 11 o’clock (two vehicles). Thirteen occupants reported a variety of injuries. Five reported cervical-strain-type complaints including three in a rear-end crash (principle direction of force 6 o’clock, change in velocity 29 kph), one in a frontal crash (principle direction of force 12 o’clock, change in velocity 14 kph), and one in a right-frontal crash (principle direction of force 2 o’clock, change in velocity 26 kph). Results indicate that, although the number of MVCs was small, no cervical-strain-type complaints were reported when change in velocity was less than 14 kph. Dynamic vehicular information obtained from the ACND at time of crash may be useful for instantaneous injury prediction. The ability to predict injury in real time may some day allow for better allocation of on-scene resources.

Key words: motor vehicle crash, communications, emergency medical services, injury, response

INTRODUCTION
Motor vehicle crashes (MVCs) that occur in urban, suburban, or other heavily traveled areas are often readily discovered and reported by bystanders or other motorists. However, MVCs that occur in rural areas or during off-hours may go unnoticed and result in delayed activation of emergency medical services (EMS). Rural areas are known to have the highest crash fatality rates in the United States, which may be partly attributable to delayed activation of EMS. At night and in remote locations, delayed activation of EMS has been shown to cause longer EMS response times.

To decrease EMS response times, especially for crashes not readily discovered, the Crash Data Research Center (Veridian Engineering; formerly, Calspan Corporation, Buffalo, NY) developed an automatic crash notification device (ACND) as part of a field operational test program performed for the National Highway Traffic Safety Administration.
(NHTSA). The ACND, which includes triaxial accelerometers, a digital signal processor, a global positioning system (GPS), and a cellular telephone was expected to decrease the time between collision and EMS notification by instantaneously detecting a crash through continuous monitoring of vehicular acceleration.

Acceleration and changes in velocity (ΔV) that exceed a predetermined threshold are recognized by the ACND processor as a crash. This threshold was established to ensure capture of all crashes likely to result in injuries of Anatomic Injury Score (AIS) 1 or above. Vehicle identification, crash location, principal direction of force (PDOF), and ΔV are relayed to a computer at the public safety answering point (PSAP) by the system’s cellular telephone (Figure 1). A voice line is opened between the emergency medical dispatcher and vehicle occupants after crash data are received at the PSAP.

Although primarily developed to increase the speed with which EMS personnel arrive at the scene of an MVC, the ACND also provides crash victims with the opportunity to receive prearrival instructions from emergency medical dispatchers. Additionally, data from the ACND may be used in real time to predict injury severity. This information could ultimately improve care provided to MVC occupants by allowing for better EMS resource allocation and treatment decisions.

This paper describes our initial experience with the ACND. In particular, the objective of this study was to determine whether an association exists between dynamic vehicle data measured by the ACND in real-world MVCs and type and severity of occupant injury, specifically cervical strains.

METHODS

Beginning in June 1997, installation of an ACND...
was offered at no cost to individuals who routinely traveled through rural portions of a single northeastern metropolitan county with a population of approximately 950,000. Population density was approximately 910 people per square mile, with 109,994 residing in rural areas. Criteria for participation included the need to drive at least 10,000 miles annually and ownership of a later model vehicle that they expected to keep for at least one year. Participants were also required to consent to a credit screening by the cellular telephone carrier. Approval was obtained by the local Institutional Review Board prior to conducting this prospective observational study.

All MVCs involving an ACND-equipped vehicle that occurred between February 1998 and June 2000 were included in the study. ACND calls were initially received via a toll-free extension at the PSAP maintained by the county sheriff. Sheriff dispatchers verified the occurrence of a crash and notified the appropriate PSAP to initiate an emergency response. Both crash data and voice communication were then routed to the county EMS dispatch center for provision of prearrival instructions if an occupant was injured. ACND project investigators were subsequently notified of the crash by sheriff dispatchers. Owners of ACND-equipped vehicles were asked to notify project investigators of collisions that were not recognized by the ACND (e.g., any crash they had experienced that did not result in an automatic phone call to the sheriff).

After they were notified that a crash had occurred, investigators contacted all MVC occupants via telephone and requested verbal consent to conduct a structured interview to identify any injuries. A written consent form was mailed to occupants at the conclusion of the interview, and medical records were obtained for those occupants who had received medical care. Medical records were reviewed, and injuries were abstracted. The list of injuries obtained by interview was used only if the occupant had not sought medical care. All occupants with cervical-strain-type injuries were identified, and PV and PDOF (Figure 2) were compared with those who did not report this injury.

RESULTS

A total of 862 vehicles were equipped with ACNDs and represented approximately 555,000 days on the road. Seventy crashes involving ACND-equipped vehicles were reported during the study period (< 1 percent). The majority of these (48) were below the crash threshold and did not trigger notification of the PSAP. No injuries were reported in these 48 crashes, suggesting that the predetermined crash threshold provided adequate specificity for injury detection.

The remaining 22 crashes exceeded this threshold; of those, 17 resulted in successful notification of the PSAP. Two of the 17 successful notification crashes occurred outside of the study area, and, therefore, no detailed follow-up was performed. Failure to successfully deliver the crash notification message to the PSAP occurred in five instances. In three of these cases, crash notification failure was due to either catastrophic damage to the ACND or loss of both primary and secondary power. Failures in the other two cases resulted from poor cell-phone coverage or malfunction of the PSAP computer.

In the 15 crashes in which there was both a successful automatic crash notification call and a detailed follow-up, there were a total of 26 occupants, 13 of whom reported injuries. Table 1 lists the frequency of injuries. Contusion was the most commonly reported injury. Cervical-strain-type injury was the next most commonly reported injury. Table 2 lists
the occupants with and without cervical-strain-type complaints and compares the ΔV and PDOF.

**DISCUSSION**

Overall, the initial operational field test of an advanced ACND successfully reduced the time to PSAP notification for crashes that required an emergency medical response. No occupant injuries resulted from any of the MVCs that were not detected by the ACND. This suggests that the predetermined ACND crash thresholds accurately excluded noninjury-producing crashes. However, there were five instances when the ACND identified an MVC but failed to notify the PSAP of the crash. These were due to destruction or loss of power to the device, lack of cell phone coverage, or malfunction of the PSAP computer.

In addition to reducing the time from crash to EMS notification, results indicate that provision of ΔV and PDOF in real time by ACNDs could prove to be a powerful injury prediction tool. This pilot study found that cervical strain was the second most common occupant complaint and occurred in rear, frontal, or near frontal collisions with ΔVs over 14 kph. However, it is important to note that other ACND-recorded crashes had similar measures of ΔV and PDOF but did not result in cervical-strain-type injuries. Further, very few crashes occurred during this pilot study. In fact, less than 1 percent of the ACND-equipped cars crashed, and none resulted in severe injuries (i.e., AIS > 2). While the limited data from this operational field test were inadequate for the development of an injury prediction model, it demonstrates the promise of this technology.

Previous research in this area by Champion et al.4 had to rely on estimated ΔV. Their Urgency Algorithm, which was developed using National Automotive Sampling System and Fatality Analysis Reporting System data, was designed to identify injuries requiring urgent care (AIS > 3).4,5 However, application of the Urgency Algorithm by dispatchers is impossible without ACND reporting of ΔV and PDOF and field calculation of ΔV and PDOF by prehospital care providers. This may not be practical given the on-scene time and expertise needed to apply the algorithm.

An automated process such as one using an ACND could prove to be a breakthrough in crash injury prediction. It has the potential to enhance the ability of emergency medical dispatchers to send the most appropriate EMS resources to the scene of an MVC. For example, this might include dispatching a helicopter sooner and may greatly reduce an injured occupant’s total prehospital time.6 Subsequent triage decisions by prehospital care providers as well as emergency physicians may also be improved by these systems.

---

**Table 1. Types of injuries sustained by occupants of ACND-equipped vehicles in above threshold collisions with successful public safety answering point (PSAP) notification**

<table>
<thead>
<tr>
<th>Type of injury</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasions</td>
<td>4</td>
</tr>
<tr>
<td>Ankle fracture</td>
<td>1</td>
</tr>
<tr>
<td>Cervical strain</td>
<td>5*</td>
</tr>
<tr>
<td>Contusions</td>
<td>10</td>
</tr>
<tr>
<td>Finger dislocation</td>
<td>2</td>
</tr>
<tr>
<td>Lacerations</td>
<td>3</td>
</tr>
<tr>
<td>Lumbar compression fracture</td>
<td>1</td>
</tr>
<tr>
<td>Sternum fracture</td>
<td>1</td>
</tr>
<tr>
<td>Radius fracture</td>
<td>1</td>
</tr>
</tbody>
</table>

* Four confirmed by medical record, one self-reported.
However, in order for this technology to reach its full potential, models must be developed and validated through further collaboration of physicians, epidemiologists, and engineers to correlate this newly available crash data with potential injuries. These models may even include detailed information and complicated algorithms that consider information such as the type of car involved, type of headrest, and seat belt use.

ACND cost per vehicle during this field test was about $1,000. However, mass production would almost certainly lower the cost and improve system reliability. First generation ACNDs are currently available on an increasing number of vehicle makes and models. These early-generation systems are triggered by airbag deployment; therefore, crashes that do not result in airbag deployment would not send an ACND crash message. This means that only in a limited set of crashes would 9-1-1 be automatically notified.

LIMITATIONS AND FUTURE QUESTIONS

This initial field test included a limited number of ACND-instrumented vehicles. As expected, the low incidence of crashes and the resulting small number of injuries limited the power of this study. Ongoing public and private initiatives to routinely instrument new vehicles with devices like the ACND that are capable of providing \( \Delta V \) and PD OF are needed to provide enough injury data to develop a reliable injury prediction model.

In addition, only minor injuries (AIS < 2) occurred during this field test. While fortunate for study participants, the limited number of severe injuries also limited our ability to develop an injury prediction model. Finally, some of the injuries were self-reported, which could have led to a reporting bias. However, there was no other mechanism to identify injuries sustained by occupants who did not seek medical attention.
**Conclusion**

Although the number of MVCs included in this study was small, no cervical-strain-type complaints were reported when ΔV was less than 14 kph, and all reported cervical-strain-type injuries occurred in rear, frontal, or near frontal collisions. Dynamic vehicular information obtained from the ACND at the time of an MVC may be useful for instantaneous injury prediction. The ability to predict injury in real time may someday allow for better allocation of on-scene resources as well as for more cost-effective patient evaluation and care.

**Acknowledgments**

This paper was presented at the American College of Emergency Physicians Research Forum, Las Vegas, Nevada, October 1999. Financial support for this study was received from the Federal Highway Administration under grant No. DTFH61-98-X-00103 as awarded by the Center for Transportation Injury Research (CenTIR).

Anthony J. Billittier IV, MD, Center for Transportation Injury Research, and Department of Emergency Medicine, SUNY Buffalo, Buffalo, New York.

E. Brooke Lerner, PhD, Center for Transportation Injury Research, and Department of Emergency Medicine, SUNY Buffalo, Buffalo, New York.

Alan Blatt, MS, Center for Transportation Injury Research, SUNY Buffalo, and Veridian Engineering, Buffalo.

Michael Viksjo, MD, Center for Transportation Injury Research and Department of Emergency Medicine, SUNY Buffalo, Buffalo, New York.

**References**