

## **Utilization of crash scene photos of vehicle damage and intrusion to improve trauma care preparedness**

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## **ABSTRACT**

### **Objective**

To design, develop, and field test a smartphone app (called TraumaHawk) that would transmit photographic vehicle crush information to a trauma center in advance of patient arrival, then determine whether such information increases the amount of lead time the trauma center has to activate and prepare for treating crash injured patients.

### **Methods**

TraumaHawk, a smartphone app for law enforcement and first responders, was designed by the University of Iowa to send photographs showing extent of intrusion and vehicle damage in a vehicle's occupant compartment to the receiving trauma center. With some basic training, first-responders and law enforcement personnel were taught how to photograph vehicles at a crash scene; trauma staff similarly received training regarding crash injury biomechanics and traumatology. For TraumaHawk cases received October 2013–August 2014, electronic medical records and trauma team notification pages were examined. Time of notification and actual time of patient arrival were noted. Time of TraumaHawk alert for these cases was also recorded. Traditional paging and TraumaHawk lead-times (minutes) were calculated. A paired *t*-test was used to determine if the mean lead-times for the Paging and TraumaHawk alerts differed significantly.

### **Results**

During the study period, 35 TraumaHawk cases were identified, and 32 met trauma team activation criteria. For these 32, actual mean time between the trauma team page and patient arrival was 12 min; for TraumaHawk, advance notice was received at the trauma center 26 minutes before patient arrival, more than doubling notification time ( $p<0.001$ ).

### **Conclusions**

Utilizing TraumaHawk to identify serious crashes remotely allowed the trauma team significantly more time to prepare for incoming trauma patients than the conventional ambulance crew notification. This allotted time allowed trauma staff to assemble a more complete and appropriate level of care by specialists, as well as to arrange other vital aspects of care—such as scheduling operating rooms.

Keywords: Motor vehicle crashes, traumatic injury, injury mechanism, prehospital

## **INTRODUCTION**

Photographic documentation of crashed vehicles at the scene can be used to improve triage of crash victims. A U.S. expert panel developed field triage rules to determine the likelihood of occupants sustaining serious injuries based on vehicle damage that would require transport to a trauma center (Sasser et al., 2011). The use of photographs for assessing vehicle damage and occupant compartment intrusion as it correlates to increased injury severity has been validated (Davidson et al., 2014). Providing trauma staff with crash scene photos remotely could assist them in predicting injuries, or in the least, determine when a crashed vehicle damage indicates severe forces to the occupants. This would allow trauma care providers to easily assess when a more traumatic crash occurred, determine the appropriate transport mode, as well as develop mental models of treatment options prior to patient arrival at the emergency department (ED).

Crash-scene medical response has improved tremendously in the past 20-30 years. This is in part due to the increasing number of paramedics who now have advanced life support (ALS) training that allows independence in the field. By adopting more advanced procedures involving a more streamlined and efficient field treatment, the paramedics are more focused on treating crash victims and may have less time, or the need, to communicate with trauma centers regarding the crash severity and potential injury mechanisms. As a result, trauma centers may not learn about severe trauma patients until just a few minutes before they arrive. If the damaged vehicle photos could be electronically transmitted from the scene to the trauma center, this would allow an advanced remote interpretation of the crash severity prior to ED arrival and provide clues about the type and severity of injury.

With strategic crash scene photo documentation, trauma professionals have been trained to assess the severity and patterns of injury based on exterior crush and occupant intrusion. In past years, training was conducted during surgery grand rounds and to ED staff at the pilot trauma center as well as at paramedic training in the region. This training focused on the principles to assess occupant compartment intrusion that increases the force that translates into injury severity and also assess the amount of exterior crush that determines the severity of force all the occupants experienced. (Tencer et al., 2005; Assal et al., 2002; Mandell et al., 2010). Again, first responders have the unique opportunity to assess and visualize the severity of damaged vehicles at the crash scene, but often the information regarding the mechanism of injury and crash severity is limited due to time constraints in the field and may not be relayed to ED trauma staff.

To integrate photographic and scene information, an app called "TraumaHawk" was created to capture images of crash vehicles and send them electronically to the trauma center. If efficiently implemented, the crash scene photos would provide the potential advantage of increasing the lead-time for ED arrival of known severely injured crash patients. Ideally, this advanced interpretation could result in better treatment and outcomes for crash victims by determining a need for airlift versus ground transport, allow more lead times for trauma preparedness for arrival, and possibly prioritize treatment plans that focus on potential injury mechanisms. In addition advanced notice can make the overall operation more efficient. Trauma staff is frequently utilized during non-emergent periods to do other

inpatient operative and bedside procedures that once started cannot be interrupted. Having some advanced lead-time for patient arrival could allow time to finish the procedure, or postpone and reschedule.

The objective of this paper is to describe the design, development, and field testing of a smartphone app (called TraumaHawk) that transmits photographic vehicle crush information to a trauma center in advance of patient arrival. We then determine whether such information increases the amount of lead time the trauma center has to activate and prepare for treating crash injured patients.

## **METHODS**

### **Background and TraumaHawk Development**

Development of the TraumaHawk app was a team collaboration that included law enforcement from the Iowa State Patrol, first responders, ALS paramedics, trauma doctors, nurses and app developers. Involving all parties was crucial in ensuring that both the app and reporting process would be intuitive and practical for all users. Figure A1 displays several screen shots from the TraumaHawk app. The design allows on-scene personnel to create a report in about one minute and transmit it electronically to the ED. The app alerts trauma staff to the exact location of the crash, and its distance from the trauma center. The report displays a series of relevant photos of the vehicles involved in the crash, and allows for added contextual information. Icons help first responders easily select specific photos to document the exterior and interior of the crashed vehicles. The few images captured allow assessment of steering wheel deformation, A-pillar compromise, roof crush and other intrusions into the occupant compartment of the vehicle that are correlated with increased injury severity (Tencer et al., 2005; Assal et al., 2002; Mandell et al., 2010).

### **TraumaHawk User Procedures**

TraumaHawk is currently implemented on Apple iPhone® 5s smart phones supplied by the state. To create a report, law enforcement or a first responder clicks on the App (Figure A1A) and then clicks “New Report” on the first screen (Figure A1B). Within the new report, the user is asked to state the type of crash (frontal, side, rollover, or rear-end); meanwhile, GPS location is also automatically logged, and calculates the distance the crash is from the Level 1 Trauma Center (Figure A1C). As can be seen in Figure A1D, the user is then guided as to what areas of the automobile should be photographed. The six areas chosen by the research team were selected based on the work by Davidson et al. (2014) that demonstrated these particular regions are most predictive of injury severity. Figure A1E shows the screen that pops up when the “Driver’s Side” option is selected in Figure A1D. The user is asked to provide three pictures of the driver’s side that together create a full side view of the vehicle, as well as 45° angled views at both corners of the damaged plane. If the user is unclear as to where the pictures should be taken, he/she can click on “Help” and view example photos of how to capture or frame the damaged side of the vehicle. Figure A1e is an example of photos taken at a TraumaHawk alert crash that illustrate the result of a high-speed near-side impact that met the intrusion rule for transport of the front right passenger to the trauma center. The field users are also allowed to include additional textual information on the crash. Nighttime photos have been successfully taken

utilizing the iPhone 5s internal flash. Additional lighting can also be provided from the high intensity flashlights that are used by law enforcement.

Finally, users have the ability to ‘sanitize’ each image by using their fingers to ‘smudge’ out crash victim faces (if present) and vehicle license plates to ensure confidentiality and protect the privacy of crash victims.

### **TraumaHawk in the Emergency Department**

Once a report has been submitted, it is electronically transmitted to the ED trauma center where the patient will be transported and displayed as an iPad® text alert; a signature auditory alarm alerts staff at the charge nurse’s station that a report has been delivered. A copy of the report is also sent to the research team via secure e-mail. The iPad report is then viewed by the ED charge nurse, who alerts the ED staff physician of the TraumaHawk notification. The ED physician reviews the TraumaHawk report and shares the photos with the Trauma team to assess crash severity, the potential for traumatic injuries, and how best to activate the trauma team most efficiently. A flow diagram of the overall process is presented in Figure 1. After the images have been received, a member of the research/trauma team communicates with the field users, mainly State troopers, who sent the photos to give them feedback on the image quality and contents. This promoted better personal communication from the field users and also provided an opportunity to discuss any factors influencing the ability or inability to capture the required photos.

TraumaHawk cases are received at the University of Iowa Hospital, which is an American College of Surgeons Committee on Trauma accredited Level 1 Trauma Center with over 600 adult and pediatric trauma beds. At this Trauma Center, in order for a trauma notification to be sent, a patient must meet certain CDC Field Triage criteria. Paramedics utilize these triage rules, examining the physiological and anatomic criteria to assess whether a patient qualifies for notification (Sasser, et al., 2011). A patient may also be considered a trauma notification for certain levels of crush and intrusion for a high-risk automobile crash. Some of the indicators of a high-risk automobile crash are defined as:

1. Component intrusion greater than 12 inches at the occupant’s site that includes the roof; or greater than 18 inches of crush at any location.
2. Patient is ejected (partial or complete) from the automobile, or
3. A death occurred in same passenger compartment, or
4. Vehicle telemetry data are consistent with a high risk of injury

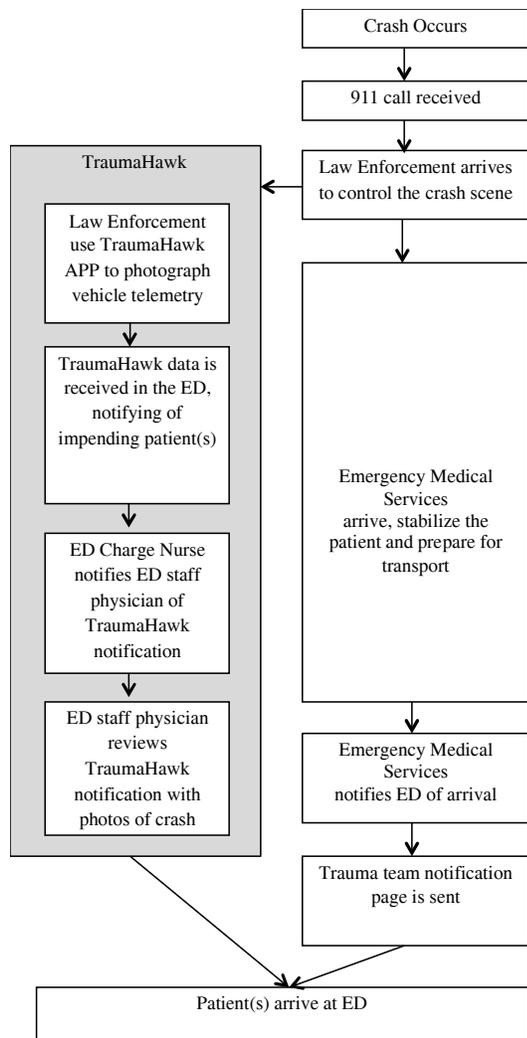


Figure 1. TraumaHawk flow diagram from crash to ED arrival

In October 2013, 15 phones with the TraumaHawk App were distributed to a convenience sample of prehospital providers, mainly to law enforcement (Iowa State Patrol), along with local county and city-based ALS ambulance services. In the first few months of deployment, we observed that the State Patrol and/or law enforcement were generally in the best position to complete and transmit the TraumaHawk reports at the crash scene. After providing first aid and traffic control, the on-scene law enforcement officer has a short window in which to capture a report once the paramedics arrive to help manage the scene. Having the on-scene photo documentation done by law enforcement does not impede on any emergency activities or delay extrication, or any patient care. The paramedics were frequently too busy with patient care priorities to pause and document the scene. However, on ambulances that carried a three-member crew, the designated driver was able to take pictures and submit a report. It should be noted, however, that each crash can have a different order of first responders to a crash scene. Depending on the crash location, particular in rural areas, law enforcement may be one of the last parties to arrive. However, they were still able to document the scene prior to patient transport, or ED arrival.

After the photos are received in to the secure email inbox and utilized in the trauma bay, they are then entered in to the patient's permanent medical record as photo attachments by hospital staff. Privacy concerns and compliance with the Health Insurance Portability and Privacy Act (HIPPA) were discussed with hospital legal counsel and the hospital compliance office. It was determined that photos that were taken by law enforcement did not constitute protected health information until they were viewed by the trauma team. However, it was felt that photos taken by EMS crews would constitute protected health information because they are using the photos as part of a medical evaluation. In these cases, any photos that contained identifiable information would need to be 'sanitized' as described above. The photos can only be sent to a password protected email inbox so that they are secure and only accessible by attending medical staff and the research team. Additional security is built into the app itself. Crash scene photos can only be accessed through the TraumaHawk app, not through the phone's camera or other photographic software. Finally, photos taken by the TraumaHawk app are perishable and are automatically deleted from the iPhone two hours after they are taken and the reports were submitted.

### **Trauma Alert Times and Trauma Registry Data Collection**

For TraumaHawk cases received from October 2013–August 2014, electronic medical records and trauma notification pages were examined to document the time and content of trauma notification pages, and the actual time of patient arrival. Time of the TraumaHawk alert cases were identified and recorded. The difference between traditional paging and TraumaHawk lead-times was calculated in minutes. A paired *t*-test was used to determine if the mean lead-times for the Paging and TraumaHawk alerts differed significantly.

To examine how TraumaHawk motor vehicle crashes (MVC) differed from all MVCs seen at the Trauma Center over the study period, hospital-based trauma registry data were abstracted for all MVCs (ICD-9 CM E-codes =E810.0-E825.7) from October 2013 through June 2014, and then analyzed. Trauma notifications were excluded if the crash involved a motorcycle or moped, all-terrain vehicle, or snowmobile that did not include a collision with a passenger vehicle; if patients were not brought directly to the Trauma Center (transferred from an outside hospital to trauma center); or if they were not brought via ground or air ambulance. Differences in proportions of TraumaHawk versus other MVCs were compared using Pearson chi-square test and differences in means were examined using a Student's *t*-test

### **RESULTS**

From October 2013 through August 2014, 35 TraumaHawk reports were received, of which 32 met the criteria for a trauma team notification. During this time, 319 eligible MVC were seen at the Trauma Center, of which 10.0% (n=32) had TraumaHawk reports.

TraumaHawk-reported patients had an average injury severity score (ISS) of 6.4 (standard deviation=11.4), 50% (n=16) were male, their mean length of hospital stay was 5.6 days (standard deviation=7.9), and the majority

(93.8%, n=30) arrived by ground ambulance. These characteristics did not differ between TraumaHawk and Non-TraumaHawk patients (see Table 1). TraumaHawk patients were less likely to be admitted (25.0% vs. 44.8%, p=0.0325) and were, on average, younger than non-TraumaHawk patients (30.8 vs. 38.6 years, p=0.0365).

	TraumaHawk		p-value
	Yes (%)	No (%)	
Age, years (mean, std)	30.8 (19.4)	38.6 (20.0)	0.0365
Male	16 (50.0)	153 (53.5)	0.7070
Arrival Mode			
Air ambulance	2 (6.3)	55 (19.2)	0.1797 <sup>1</sup>
Ground ambulance	30 (93.8)	230 (80.4)	
Police	0	1 (0.4)	
Injury Characteristics			
ISS	6.4 (11.4)	8.0 (10.5)	0.5020
Max AIS	1.7 (1.3)	2.0 (1.2)	0.1721
ED GCS	14.6 (1.3)	14.3 (2.7)	0.2256
TRISS	0.97 (0.07)	0.95 (0.16)	0.2383
Admitted to Hospital	8 (25.0)	128 (44.8)	0.0325
Length of stay, days (mean, std)	5.6 (7.9)	5.2 (8.3)	0.8811
Died	0	7 (2.5)	0.9999 <sup>1</sup>

<sup>1</sup> Fisher's exact test

Of the 32 TraumaHawk cases who were also trauma notifications, the actual mean time between the trauma team page and patient arrival was 12 minutes; with TraumaHawk, the advanced notice was received at the trauma center 26 minutes before patient arrival, more than doubling notification time (p<0.001). On average, the ED doctor saw patients 69 minutes after they sustained their injury. These times were significantly lower for TraumaHawk patients (56.7 minutes, standard deviation=23.3) than for non-TraumaHawk patients (70.2 minutes, standard deviation=43.8) (p=0.03). In addition, the trauma surgeon responded, on average, 66 minutes after the injury. TraumaHawk patients saw the trauma surgeon, on average, 58.1 minutes (standard deviation=22.1) after their injury vs. 67.3 minutes (standard deviation= 36.0) for non-TraumaHawk patients (p=0.07).

The TraumaHawk reports averaged six (range 1-14) photos per report. In the 35 TraumaHawk reports, 88.6% included interior images of the driver area with a view of the steering column, and 80% showed a view of the driver floorboard. In all cases, the damage planes were documented.

## **DISCUSSION**

Advanced warning and trauma page activation regarding an incoming crash allows ED personnel to allocate resources more efficiently. They are able to order the disposition of patients and allocate adequate staff to receive incoming crash victims. The increased time afforded by a trauma alert also allows trauma surgeons and specialty services to adjust schedules accordingly (i.e., they might delay the start of a non-urgent scheduled procedure to provide time to assess the incoming trauma victim).

While all trauma staff receive a standardized page with a report from the field, this often includes only the most basic information about the manner of collision such as frontal crash, rollover; some vital sign information and potential body region injury may also be described. It is said that, “a picture is worth a thousand words”. Some of the feedback from trauma staff indicated that the viewing of the TraumaHawk report images prior to a patient’s arrival allowed a much better assessment of potential injury than a brief radio report would. This assessment did enable the trauma team to prepare and plan for specific key treatment and specialties services (orthopedics, neurosurgeon, etc.) such as the case in identifying the potential for a pelvic fracture for the patient in Figure A1E.

TraumaHawk is a useful tool to teach the basics of automotive traumatology. This is a complex science that involves an understanding of restraint systems, physics, occupant factors, and crash dynamics. Having a basic understanding of traumatology, one can correlated the damage crush and intrusion into the vehicle to potential severe injury patterns, as well as measure the extent of force in which the passengers may have sustained. This then can help shape the mental model of treatment by EMS and trauma care providers. A crash injury mechanism curriculum had been created by the team and delivered to all users by an in-person presentation during this pilot phase. The course has been certified to provide continuing medical education (CME) credits. The course illustrates the basic methods on how to interpret the Step 3 CDC rule examining damage planar crush and the potential injury patterns from intrusion. Currently several short topic modules are being created from this curriculum that can be reviewed electronically by law enforcement, prehospital personnel, nursing, and trauma staff. This curriculum will be a required component of the using the information generated from the app and the modules would also be available to the users on the iPhone. We see that such a series of courses would become standard training for all personnel involved in the treatment of crash victims.

Improving the mental model of crash dynamics and potential injury has several potential advantages on patient care. In the prehospital setting, when used in conjunction with the CDC trauma guidelines it can help to determine whether to take the patient to a level II or III trauma center for treatment or whether to bypass one of these closer

hospitals in favor of going directly to a level I trauma center. TraumaHawk reports can help to make determinations about which patients should be transported by air ambulance versus the standard ground transport. The research did not evaluate if TraumaHawk impacted these decisions or transport modes. Further research is planned to evaluate after the pilot with TraumaHawk procedures are in place.

Once in the hospital, all patients undergo a standardized and very thorough exam. The photos generated by the TraumaHawk app can help the team focus on particular parts of the exam where the data would indicate there is a high risk for injury. Conversely, if a patient appears to be uninjured or has very mild injuries after a full and thorough exam, having an understanding of the crush patterns of the vehicle (or lack thereof) can provide the treating team with reassurance that the patient is safe for discharge and could reduce the need for invasive procedures and radiological images. Current prehospital treatment protocols are always in place to examine patients, and even in low speed crashes occupants can still be severely injured and not have significant crush. As this was an implementation pilot, trauma staff feedback and communication regarding its use was conducted. This generated some positive responses from ED staff, especially the additional time to prepare trauma bays and schedule the potential need for operating rooms and some pre diagnosis of potential mechanism of injury.

There are limitations to this study. First, TraumaHawk crashes tended to occur in closer proximity to the ED than did non-TraumaHawk crashes; therefore we cannot say if the shorter time between patient injury and the ED/Trauma physician was perhaps due to the shorter distance traveled. Second, because there are only a small proportion of MVCs seen at the ED with TraumaHawk reports, the generalizability of the current results are limited, although, the characteristics of TraumaHawk patients and their injuries did not differ greatly from non-TraumaHawk patients.

From these pilot data, TraumaHawk was shown to increase the advance time for trauma notification and preparedness at a trauma center for identified trauma patients. Because of the added context, patients were seen more quickly than non-TraumaHawk cases. Since the initial 15-phone deployment, we have increased the number of phones to 35 in state trooper vehicles, and more data will be available soon. With the success in the implementation of TraumaHawk, further research and evaluations are planned to examine the benefits in the triage, transport and treatment of crash victims.

## **CONCLUSIONS**

Utilizing TraumaHawk to identify serious crashes and potential injury mechanisms allowed the trauma team significantly more time to prepare for incoming trauma patients than the conventional ambulance crew notification. This allotted time allowed trauma staff to assemble a more complete and appropriate level of care by specialists, as well as to arrange other vital aspects of care—such as scheduling operating rooms.

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FIGURE A1

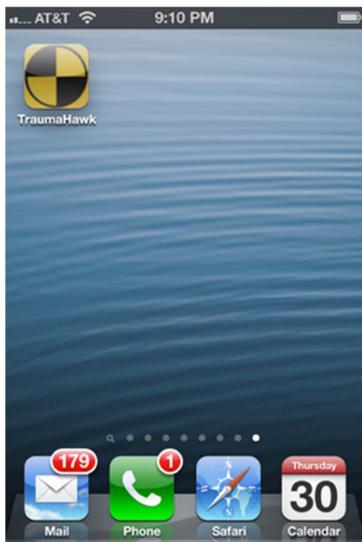


Figure A1a



Figure A1b



Jul 08, 2013 10:18 AM

- Frontal     Side
- Rollover     Rear-End



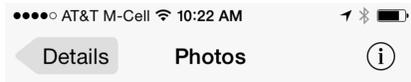
Distance: 10135.53 km

[Change Hospital](#)

University of Iowa Hospitals and Clinics

**Next**

A1c



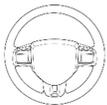
Choose the area to photograph



Front View



Driver's Side



Steering Column



Floorboard



Rear View



Passenger's Side

**Submit**

A1d



Ale

Figure A1. TraumaHawk iPhone 5S interface and screen shots

FIGURE A2

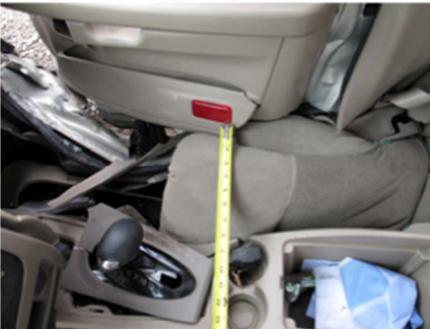


Figure A2. Example images from a TraumaHawk crash file