

**IN-DEPTH ACCIDENT STUDY ON D-CALL NET VEHICLES
BY MEDICAL ENGINEERING COLLABORATION**

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ABSTRACT

D-Call Net, which Japan was the first country in the world to implement for practical use, is an extremely unique advanced automatic collision notification system in which a helicopter emergency medical service (HEMS) with a doctor and a nurse on board is requested by a vehicle involved in a collision. Six years have passed since the start of a pilot operation and four years since the start of a commercial operation, and more than twenty cases have been reported in which D-Call Net has activated HEMS and transported drivers or passengers to trauma centers. Since 2018, the Ministry of Economy, Trade and Industry (METI) has been supporting the international standardization activities of the injury estimation algorithm used in D-Call Net. Based on the newly established Japanese Industrial Standard (JIS) D0889 [1], ISO standardization activities are continuing to develop the technical specification under ISO TC22/SC36/WG7.

On the other hand, from FY2021, the Ministry of Land, Infrastructure, Transport and Tourism initiated the "D-Call Net In-Depth Accident Study" in which experts in emergency medicine and automotive engineering collaborate to establish an accident database for developing safer vehicles, replacing the previous "Medical Engineering Collaborative In-Depth Accident Study".

Institute for Traffic Accident Research and Data Analysis (ITARDA) has been in charge of both ISO standardization activities and the accident studies. This paper provides an executive summary of ITARDA's D-Call Net In-Depth Accident Study for FY2021. A total of twenty-one collisions were investigated during the study period, and several characteristic collisions were selected and detailed among them. The consideration of ΔV recorded by EDR, the time saving effect of D-Call Net and the evaluation of the algorithm according to the ISO technical specification are also discussed.

INTRODUCTION

In Japan, the Automatic Collision Notification system, HELPNET, had been in service since 2000, automatically transmitting the collision location and other information to the Answering Point in the event of a collision such as airbag deployment, and transferring the information to Fire Head-quarters for prompt EMS activities.

The newly developed D-Call Net was a further enhancement of HELPNET, and its additional functions included automatic transmission of vehicle information such as severity and direction of collision, belt use and others to the Answering Point, as well as collision location. The system also uses the algorithm [2, 3] to estimate the probability of fatal or serious injury to the driver and front passenger. The estimated results are transmitted in real-time to the trauma center with HEMS, enabling an early decision to dispatch a helicopter or a rapid car, and significantly shortening the time until the start of treatment by a medical doctor. (See Figure 1)

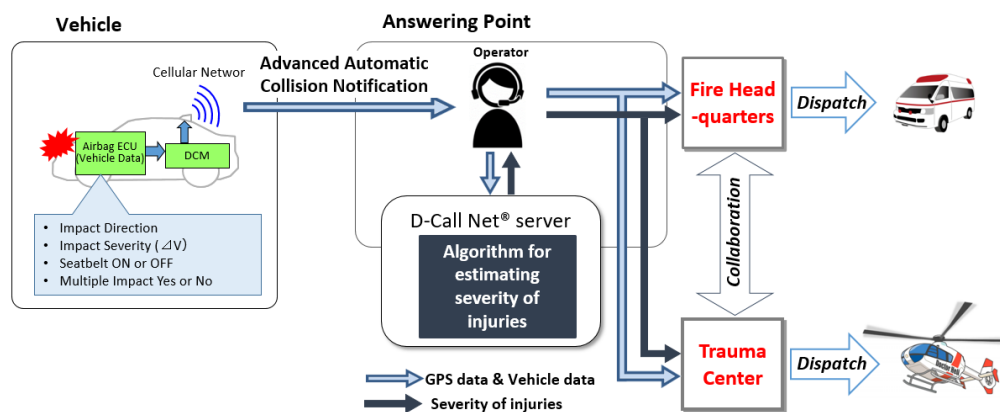


Figure 1. Outline of D-Call Net

In November 2015, Toyota Motor Corporation and Honda Motor Corporation together with HEM-Net had started a pilot operation of D-Call Net, and commercial operation had begun in April 2018 [4]. Subsequently, in 2019, Nissan Motor Corporation and Mazda Motor Corporation began selling vehicles equipped with D-Call Net, and in 2020, Subaru Corporation also began selling vehicles equipped with D-Call Net. In HEMS, a medical doctor and a nurse are trying to shorten the contact time with traffic accident victims with a strong desire to save lives. ITARDA had been conducting the "Medical Engineering Collaborative In-Depth Accident Study" for vehicle safety as a research commissioned by MLIT, in order to obtain basic data for vehicle safety measures. The study was conducted by setting up a "Study Group for Detailed Investigation and Analysis of Traffic Accidents by Medical Engineering Collaboration" consisting of academic experts, medical professionals, researchers from traffic safety-related research institutes and engineers from vehicle manufacturers. The committee members could access the accident data. Some members wished to make free use of the accident data, but such free use was never approved because accident data was specific information under the Road Traffic Law. As a consequent, this committee closed its activities in FY2020.

On the other hand, the injury estimation algorithm used in D-Call Net had been registered as JIS D0889, and its evaluation was ongoing, but the number of accident cases to compare the estimated injury level with the actual injury level has never been sufficient. Therefore, in place of the medical and engineering collaborating in-depth accident study by FY2020, a new research project had been initiated to establish the all-Japan investigating structure and to accumulate accident data as a database, in cooperation with automobile manufacturers that produce vehicles equipped with D-Call Net.

At previous ESV conferences, Toyota Motor Corporation had made presentations on D-Call Net [5, 6], but this time, ITARDA introduces the recent study in all-Japan collaboration.

METHOD

Joint Research Consortium

The objective of this study is to prepare basic data for the investigation and collection of D-Call Net accident cases for continuous evaluation on D-Call Net effectiveness and operations, as well as to establish accident database in cooperation with medical and engineering. Although there had been no collaboration with MLIT for the previous study [7], MLIT proposed the establishment of a "Joint Research Consortium" centered on ITARDA in which MLIT would support the research and all manufacturers of vehicles equipped with D-Call Net would provide information of collision notification to ITARDA to establish the accident database. (See Figure 2)

Joint Research Consortium

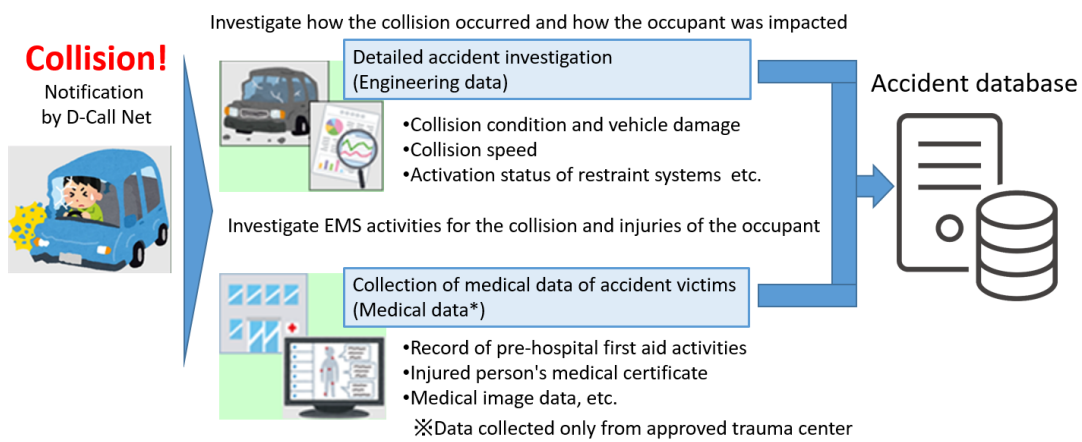


Figure 2. MLIT's medical and engineering collaborated accident database

The structure of the whole joint research is shown below, and the number of HEMSs subject to this research was sixty-one trauma centers and fifty-three helicopters in forty-four prefectures, as of the end of July 2022. Five manufacturers that currently provide vehicles with D-Call Net and National Research Institute of Police Science (NRIPS) were also participating in the joint research. (See Figure 3)

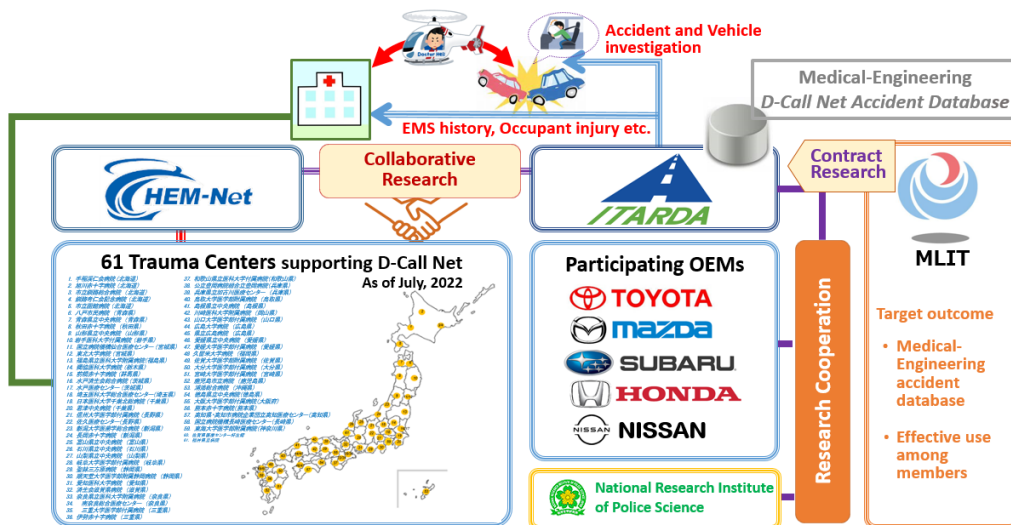


Figure 3. ITARDA's collaborative research project in all-Japan

Procedure of D-Call Net Accident Investigation

The basic premise of the in-depth accident study conducted by ITARDA is to obtain consent from the parties (often drivers) involved in a traffic accident before starting the in-depth investigation. Therefore, in the D-Call Net study as well, it is a prerequisite to obtain consent from the drivers of vehicles equipped with the D-Call Net and other related parties. Since collisions involving D-Call Net-equipped vehicles occur nationwide in Japan, coordination with the National Police Agency (NPA) and prefectural police headquarters was essential in order to obtain information on the subject accident cases. When ITARDA is notified of the occurrence of D-Call Net case, ITARDA informs the date, time, and location to NPA. NPA provided ITARDA with the contact information of the police headquarters in the relevant prefecture. Based on this information, ITARDA contacts the police headquarter with the jurisdiction, explains the circumstances of the accident investigation and obtains information on the driver involved in the collision from the police officer in charge of the case. ITARDA then contacts the driver directly and obtains his consent to the in-depth accident investigation.

RESULTS

Overview of Accident Cases Investigated

In the first year's joint research on D-Call Net accident investigations, the results of twenty-one cases that occurred from January to December, 2021 were investigated with the consent of the drivers involved, including cases in which HEMS or Rapid Car was dispatched, are summarized below.

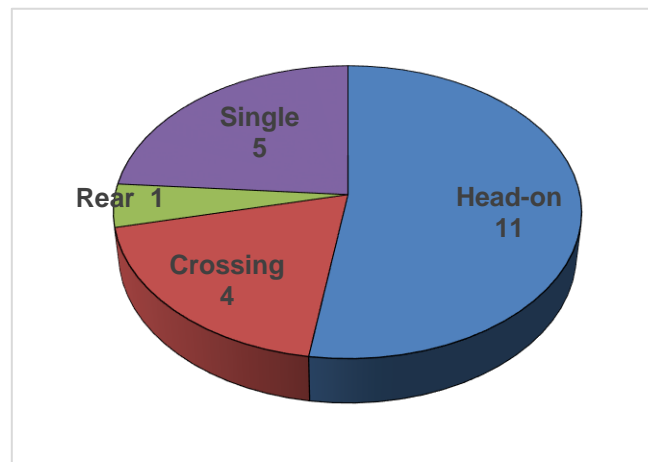


Figure 4. Collision types of 21 D-Call Net accidents investigated.

The distribution of collision types for the twenty-one vehicles equipped with D-Call Net was shown. Among them, eleven vehicles were head-on collisions, four were crossing collisions, and one was a rear-end collision with the other vehicle. In addition, there were five single vehicle collisions, mostly frontal collisions. (See Figure 4)

The plots of “delta V” versus “Predicted injury probabilities” for 24 occupants (twenty-one drivers and three front passengers) on the twenty-one vehicles were shown. Each plot was classified by the actual level of injury revealed by investigations, such as Severe, Minor or No injury and Unknown, as color-coded. (See Figure 5)

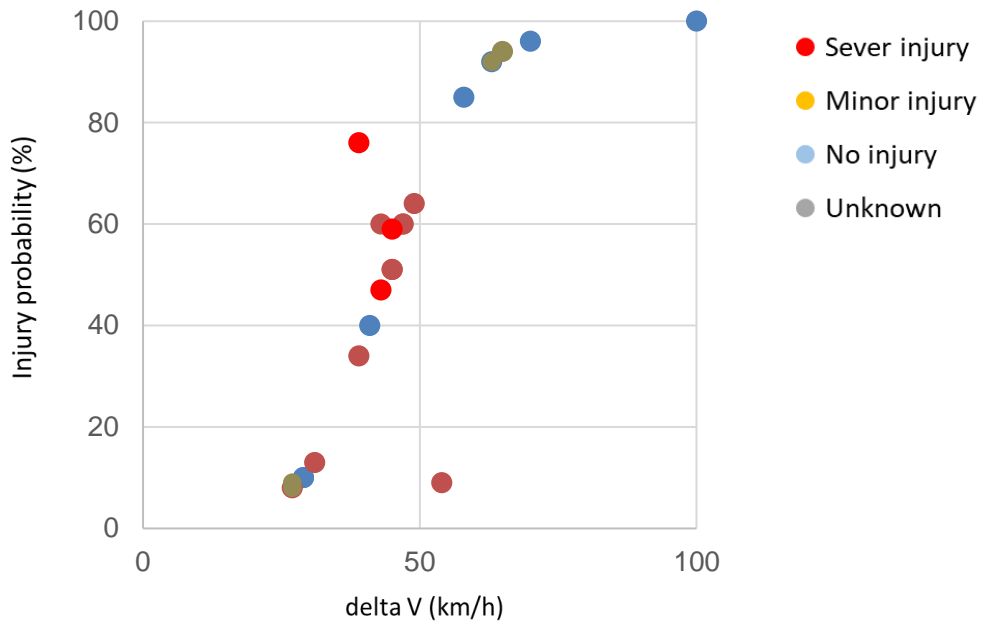


Figure 5. Injury outcomes of twenty-four occupants

Representative Examples of Distinctive Cases

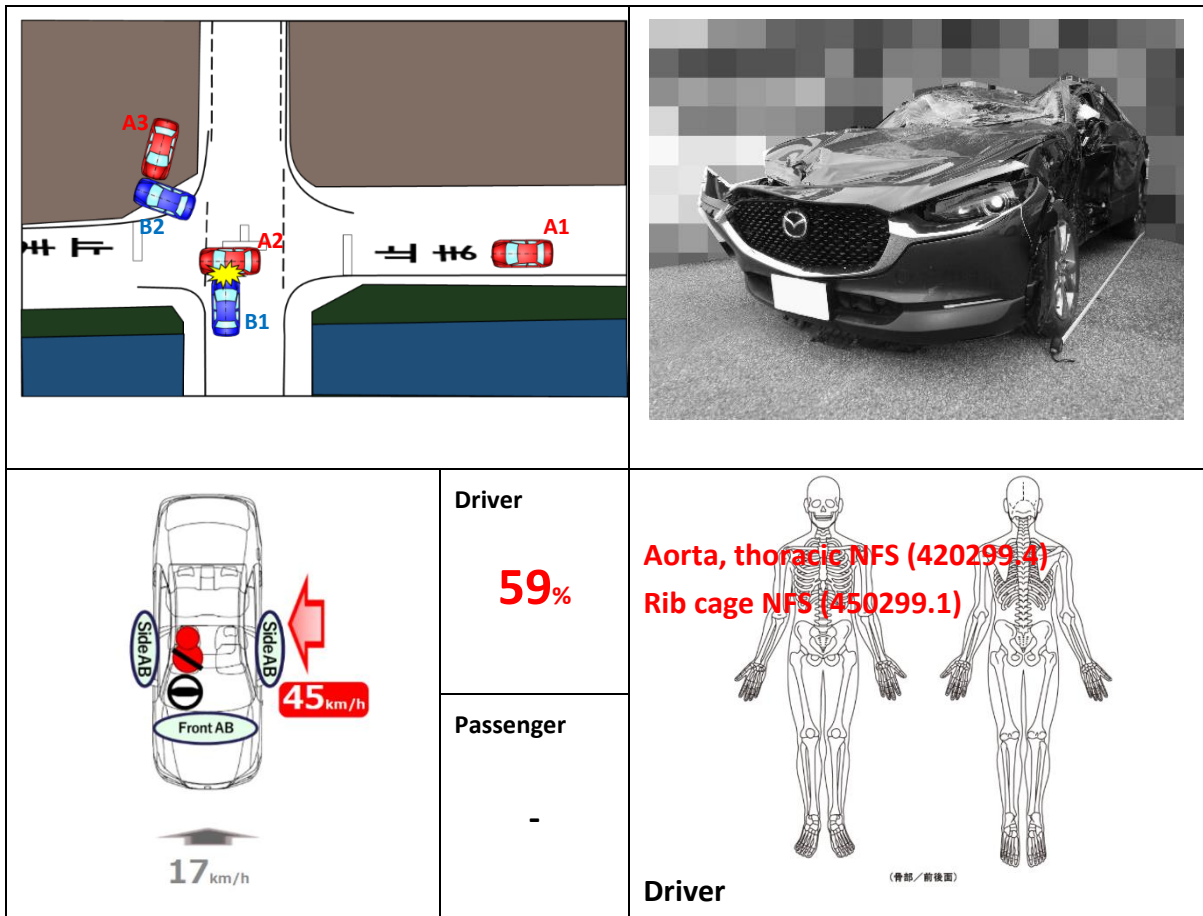
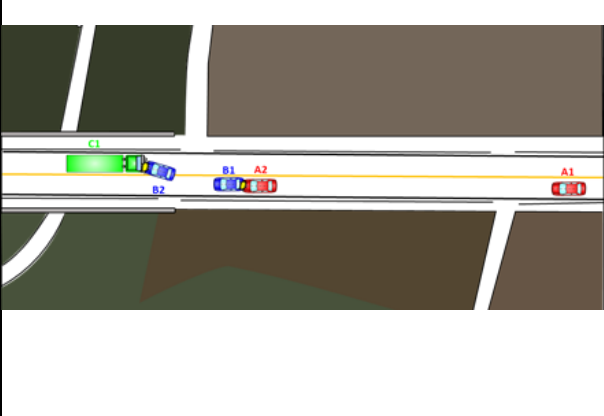


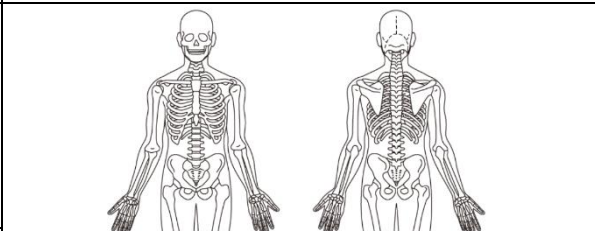
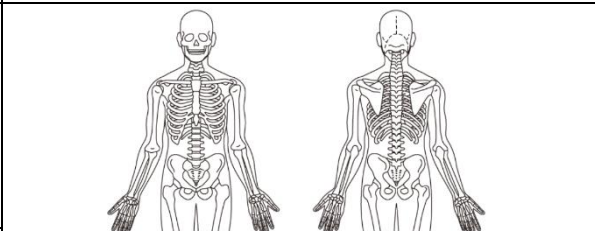
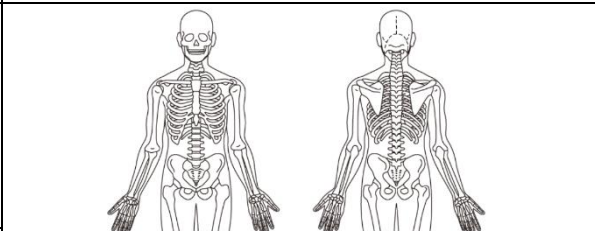


Figure 6. Accident summary of Case No. 1

This collision occurred in Shiga prefecture in the morning. A passenger car “A” was traveling on a single road along a canal. When it entered an intersection with a stop sign without stopping, it collided with a passenger car “B” proceeding from the left side of the crossing road and finally caused rollover off the road. The fatal or severe injury probability was 59%, and HEMS was activated. As the driver’s severe injury was estimated, the actual driver’s injuries were traumatic aortic rupture (420299.4) and rib fracture (450299.1) according to medical information provided by the trauma center [8]. In spite of far-side impact to passenger’s side, a large deformation was observed on the door of driver's side, which may have been caused by a secondary impact with a guardrail at the intersection. Furthermore, the roof was also severely deformed due to rollover, and not enough survival space for the driver was secured. During both side impacts and roll over, the driver sustained serious chest injuries.

In this case, the early start of treatment by HEMS was effective, however it took 25 minutes from the time the trauma center became aware of the collision until the HEMS took off. Then, the time-saving effect of the D-Call Net could not be confirmed. Since no information was provided by the trauma center, the cause of this delay until take-off remained unclear, but the HEMS was most likely requested by the EMS team after arrival at the scene. For HEMS activated cases, it is important to improve collaboration between trauma centers and ITARDA so that they can provide information not only on the time lapse but also on the circumstances of the incident.

CASE No.2: Severe frontal impact Rapid car was dispatched by D-Call Net

					
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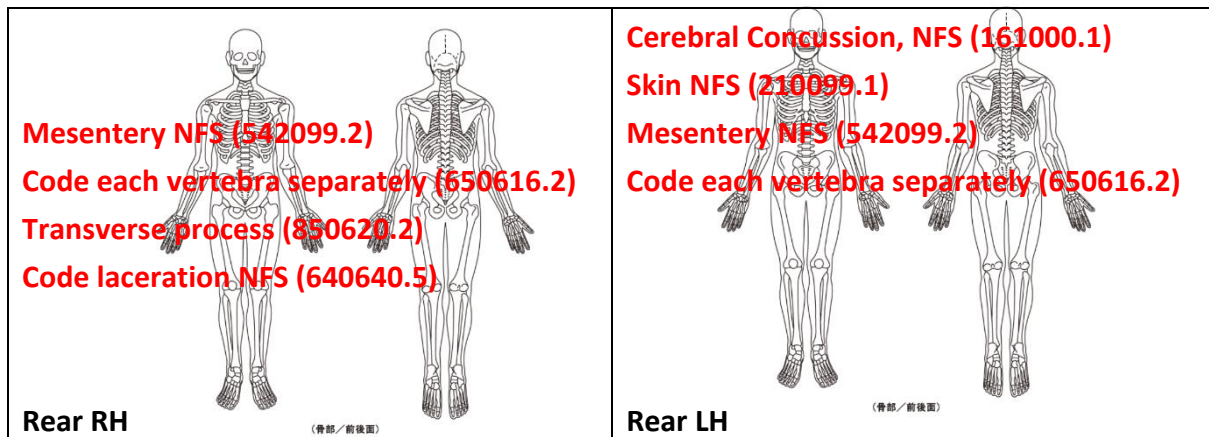


Figure 7. Accident summary of Case No. 2

This collisions occurred in Chiba prefecture at night. A compact passenger car “B” equipped with D-Call Net was proceeding on a road with one lane in each direction, and was waiting for oncoming vehicles to pass in order to turn right into an off-road facility. A following standard freight vehicle “A” collided against the rear of the car “B”. As the result, it was pushed forward and moved into the oncoming lane, where it collided head-on with a large freight vehicle “C”, proceeding straight ahead in the opposite direction. The predicted fatal or severe injury probability was as high as 94%. Because it was beyond the time period for HEMS operations, the Rapid Car (doctor car) was dispatched instead.

On the car “B”, there were two occupants with seatbelt in rear seats, and they sustained severe injuries and were transported to the trauma center. Both of them sustained serious injuries to the abdomen and lumbar spine, but the causes of those injuries were most likely the seat belt (lap belt area). Another factor that may have contributed to their injuries was the fact that the car “B” was collided rear-ended by the vehicle “A” first and their upper bodies were tilted backward and that it collided head-on by the vehicle “C” shortly after the first impact. The occupant on the left rear seat suffered a head injury from the secondary impact against the front seat back resulted in a less severe lumbar spine injury than the occupant on the right. (See Figure 8)



Veh. A : Standard freight vehicle



Veh. C : Large freight vehicle

Figure 8. Deformation of other vehicles

Case No.3: Severe front impact against object

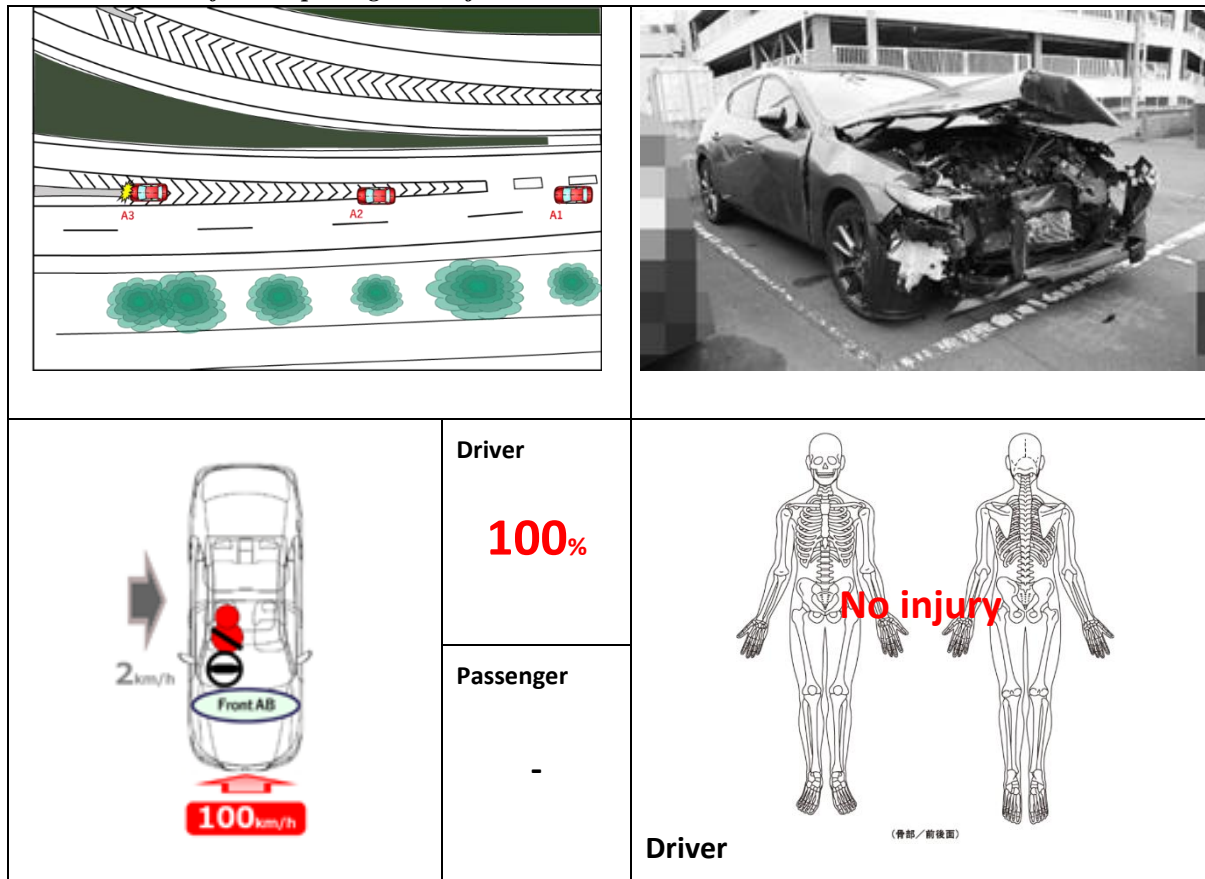


Figure 9. Accident summary of Case No. 3

This collision occurred at a junction of expressway in Tochigi prefecture late at night. The probability of fatal or severe injury of the driver was 100%, but no HEMS was activated because of the unavailability of night flights. An in-depth accident investigation was conducted with the driver's consent and the results revealed that it was an extremely rare case in which the driver was uninjured, regardless of the 100% probability of fatal or serious injury. Although there have been many over triage cases in the past investigations, this was the first case in which the driver was uninjured even at 100% probability. Hence, it is also addressed in this paper.

The investigation of the accident site revealed that the vehicle “A” collided head-on with a crash-impact absorber located at the junction of the main line and the off-ramp on the expressway, and the driver was presumed to have been uninjured because the structure effectively absorbed the vehicle impact energy, the cabin deformation was minimal and the restraint system was functioning, etc. The deformed absorber at this accident spot and a similar crash impact absorber without deformation are shown below (See Figure 10).

Observation of the vehicle involved in the accident revealed that the passenger compartment remained intact, and there was no significant setback of the steering wheel. In addition, the driver's airbag and knee airbag also deployed and all restraint systems functioned as intended. These facts were believed to have contributed to the driver's non-injury.



Deformed absorber at accident spot



Undeformed absorber elsewhere

Figure 10. Deformed and Undeformed absorber

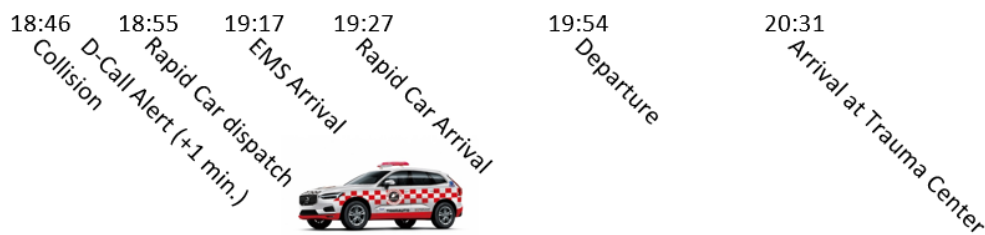
DISCUSSION

Regarding the second case, the HEMS base trauma center provided a timeline of EMS events (See Table 1). The fact that the rapid car was dispatched prior to the arrival of the EMS ambulance at the accident spot indicated that the rapid car was activated by D-Call Net alert only, not by the on-scene request from the EMS team. A time saving effect of twenty-two minutes was confirmed. Then, this is a typical case in which the D-Call Net functioned effectively to activate the rapid car.

The driver of the car “B” was transported to another trauma center (detailed injury information was not obtained), and the two rear seat passengers of the car “B” were transported by ambulances to the trauma center. If the helicopter had been able to fly at night, one of the two seriously injured rear seat passengers would have been transported by HEMS and fundamental treatment could be initiated early. Nighttime flight of HEMS is considered to be one of the future issues.

Table 1.

Time lapse of the emergency medical event



Using the validating methodology with reference to ISO DTS 4654 (Road vehicles – Advanced automatic collision notification (AACN) systems – Methodology for creating and validating algorithms for injury level prediction) which is still in development at the task force under ISO TC22/SC36/WG 7 (Traffic accident analysis methodology), the evaluation of the injury prediction algorithm used for D-Call Net was carried out. Seventeen drivers and three front passengers had their actual injury levels in this study, except for four unknowns. The “Confusion Matrix” proposed by ISO DTS 4654 is shown. (See Table 2)

Table 2.

Confusion Matrix for the prediction in this study

		Estimated injury level	
		Fatal or Sever (+)	Minor or No (-)
Actual injury level	Fatal or Sever (+)	True Positive 3	False Negative 0 (Under triage)
	Minor or No (-)	False Positive 17 (Over triage)	True Negative 0

- In case of normalization against actual classes,

$$OTR = FP / (FP + TN) \quad \text{Equation (1)}$$

Then, OTR = 1.0

- In case of normalization against predicted classes,

$$OTR = FP / (FP + TP) \quad \text{Equation (2)}$$

Then, OTR = 0.85

There is no “True Negative” case in the table. D-Call Net vehicle manufacturers participating in this joint research tend to provide ITARDA with information on collisions with high injury probabilities. Then, the bias of the sampling to focus on cases where HEMS might be dispatched resulted that there is no case predicted minor or no injury. During this study period, the threshold of predicting fatal or severe injury provability was 5% or more. All cases investigated by ITARDA had probabilities from 8% to 100%. Therefore, no “True Negative” case was investigated. Separating this in-depth study, manufacturers are strongly expected to accumulate and analyze all D-Call Net notifications that ITARDA is not able to know about.

An Event Data Recorder of the investigated vehicle with D-Call Net was often retrieved. The EDR of the third case vehicle was also retrieved. The vehicle speed at time of collision was 128 km/h and the maximum delta V was -140 km/h. According to the wave form of the delta V values decreased almost linearly and the values at time of 200 msec. was recorded as -110 km/h and at time of 250 msec. as -132 km/h, unfortunately, the waveform itself was not allowed to be included in the paper.

The delta V received at the answering point was 100 km/h and fatal or severe injury provability was calculated as 100 %. The driver experienced the deceleration as around 15 Gs during the collision against an absorbing structure for over 250 msec. The restraint system was activated properly and the driver was not injured at any body region. In this case, the algorithm used by D-Call Net itself never failed to predict injury probability. Regarding delta V value, the condition experienced by the driver was statistically resulted fatal or severe injury. About 50 % over triage rate is approved in D-Call Net and this case should be one example of the unique over triage case.

At present, very few trauma centers activate their HEMS based on D-Call Net alert only. Therefore, there is a desire to broaden the scheme of immediate dispatch by D-Call Net alert only. However, ITARDA’s longstanding experiences from D-Call Net accident investigations suggest that deep consideration might be required for it.

CONCLUSION

From FY2021, ITARDA carried out the joint research commissioned by MLIT, which was started in place of the previous in-depth accident investigation by medical-engineering collaboration. The objectives of this joint research was to evaluate the D-Call Net effectiveness, system itself and operations, and to investigate and collect D-Call Net accident cases in cooperation with vehicle manufacturers and trauma centers with HEMS.

In the first year, in cooperation with the Japan Automobile Manufacturers Association (JAMA), we concluded agreements with all manufacturers of vehicles equipped with D-Call Net such as Toyota Motor Corporation, Mazda Motor Corporation, Subaru Corporation, Honda Motor Corporation and Nissan Motor Corporation. The all-Japan D-Call Net in-depth accident investigation structure had made it possible to receive a large amount of alert information. With the support of NPA, each information was referred to prefectural police headquarters, and with the consent of the drivers involved, twenty-one in-depth accident investigations were completed.

The twenty-one drivers and three front seat passengers on the twenty-one vehicles were examined, comparing predicted injury probabilities and actual injury outcomes. The results were: three True Positive cases, No “True Negative” case, seventeen “False Positive” (Over Triage) cases, and no “False Negative” case. The absence of “True Negative” and “False Negative” cases is due to the fact that accident cases estimated to be less than 5% were not investigated in this study.

FUTURE ISSUES

In order to understand the time-saving effect of D-Call Net, it is essential to know the time lapse of the emergency medical events in each case, as the second case. Currently, however, only a limited number of cooperating trauma center with HEMS were able to provide the time lapse information to ITARDA.

To solve this problem, ITARDA, in cooperation with HEM-Net, proposed the additional tag for D-Call Net cases to the HEMS registry at the 28th Annual Meeting of Japanese Society for Aeromedical Services held in Kumamoto, and is currently coordinating with the registry secretariat. ITARDA plans to start providing support to the registry office for the tagging in the next fiscal year. In addition, ITARDA plans to establish a joint research with some trauma centers, subject to approval by the trauma center's ethical committee, for the purpose of providing various types of information when dispatching its HEMS.

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