

EVALUATION OF THRESHOLD USED BY ADVANCED AUTOMATIC COLLISION NOTIFICATION SYSTEM FOR DISPATCHING DOCTORS TO ACCIDENT SITES

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ABSTRACT

An advanced automatic collision notification system (AACN) called “D-Call Net” started operation in Japan at the end of 2015. D-Call Net reports both the location of the accident and the probability of serious and fatal injuries calculated based on event data recorder (EDR) information such as the collision direction, delta-V, seatbelt usage, and whether multiple impacts occurred. This information is sent simultaneously to fire departments and emergency responders at hospitals operating air ambulances to shorten the duration before a doctor reaches the injured as much as possible. The probability of serious or fatal injury used by D-Call Net was calculated by Toyota Motor Corporation and Nihon University based on 2.8 million items of crash data in Japan. This probability was developed using only driver side data, and is also applied to the passenger side. The recommended threshold for dispatching a doctor to an accident site is currently set to a 5% probability of serious or fatal injury, which means that the under-triage (UT) rate does not exceed 10%. This research investigated 374 accidents notified via D-Call Net to determine whether the current threshold of 5% is appropriate. This investigation found that the UT rate was 0%, the over-triage (OT) rate was 29%, and that the correct judgment was made in 71% of cases. These results satisfy the targets set when operation of the system started (UT: 10%, OT: 61%). This paper also discusses the appropriate threshold for dispatching doctors via D-Call Net to further reduce the rate of unnecessary emergency dispatches.

1. INTRODUCTION

The number of traffic accident fatalities in Japan in 2017 was 3,694 (here, “traffic accident fatality” is defined as a death occurring within 24 hours of an accident). Although this is the lowest number since statistical records began [1], it still represents a significant loss of life. The target set by the Japanese government is lower than

2,500 annual traffic accident fatalities by 2020 [2]. Although the number of fatalities is declining, the rate of decline has fallen off in recent years, and this target will likely be difficult to accomplish (Fig. 1).

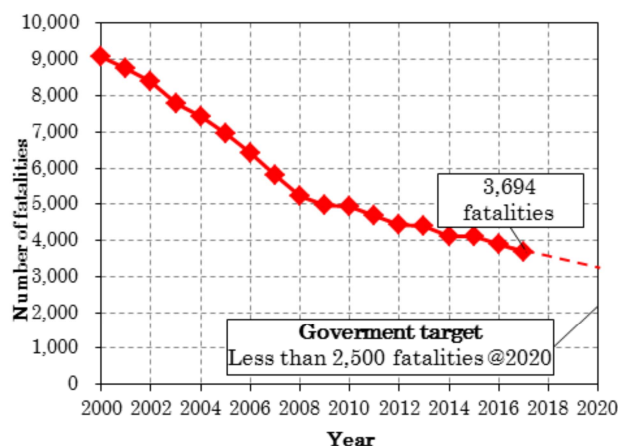


Figure 1. Traffic accident fatality trends in Japan.

Automatic collision notification (ACN) systems and advanced versions of these systems (advanced ACN, or AACN) are being adopted in increasing numbers around the world as telematics technologies become more prevalent. These systems are regarded as an important means of further reducing traffic accident fatalities, and effective application is desirable to promote the effectiveness of post-accident emergency treatment.

In Japan, an AACN system called “D-Call Net” entered full-scale operation in April 2018. This system combines medical and technical information to transmit injury probability information to fire departments and hospitals operating air ambulances, with the aim of reducing the time before medical staff can start emergency treatment (Fig. 2).

The purpose of ACN is to speed up the provision of medical treatment by automatically notifying emergency teams when an accident occurs. These systems facilitate the provision of more appropriate emergency treatment by transmitting data such as the location and the color of the vehicle. However, the effect of these systems in shortening the time before treatment is limited to a 4-minute reduction in accident notification times [3]. The EU mandated the installation of a system called “eCall” in all new vehicles from March 31, 2018. In addition, Russia mandated that new models must be equipped with a system called “ERA-GLONASS” from January 2015. This was extended to all production vehicles from January 2017. Other countries are also studying making ACN systems a legal requirement.

In contrast, D-Call Net automatically transmits information from vehicle event data recorders (EDRs). This system predicts the seriousness of injuries in the accident by applying this data to a mathematical model called an injury prediction algorithm. It then determines whether to dispatch medical staff to the accident site in accordance with the predicted injury severity.

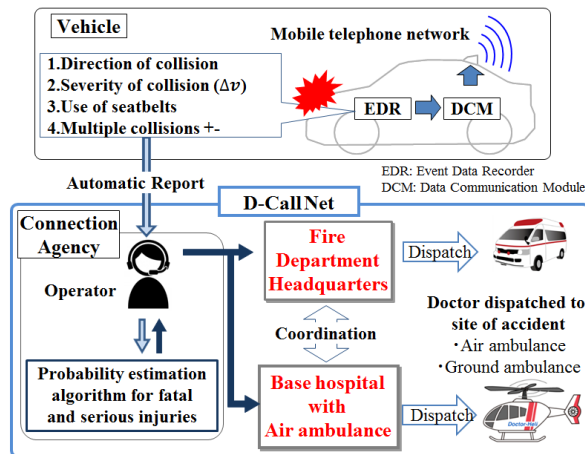


Figure 2. Information transmitted by D-Call Net

If the algorithm predicts that rapid emergency treatment is required, this system automatically transmits the information shown in Fig. 3 directly to base hospitals operating air ambulances through a call center called “HELPNET” (run by an organization called Japan Mayday Service Co., Ltd.). The purpose of dispatching medical staff in air ambulances or medical vehicles to the accident site in this way is to speed up the provision of emergency treatment.

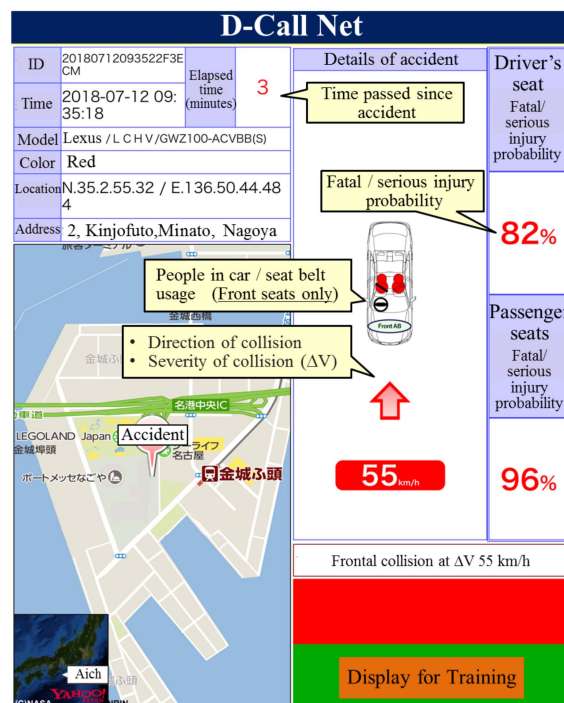


Figure 3. Information transmitted by D-Call Net.

Without this system, the average time required for an air ambulance to reach the accident site and begin treatment is currently 38 minutes. In field tests using vehicles equipped with D-Call Net, treatment was started

in 21 minutes, a saving of some 17 minutes (Fig. 4). It was provisionally calculated that rapid notification of the probability of serious or fatal injury to the occupants of vehicles equipped with the system or other vehicles involved in accidents to fire departments or hospital emergency departments would reduce the number of annual traffic accident fatalities in Japan by 282 people [8]. However, information about the probability of serious or fatal injury is currently limited to front seat occupants of vehicles equipped with the system. It would be beneficial to generate and transmit this information about rear seat occupants, pedestrians, cyclists, and occupants of other vehicles involved in accidents, as well.

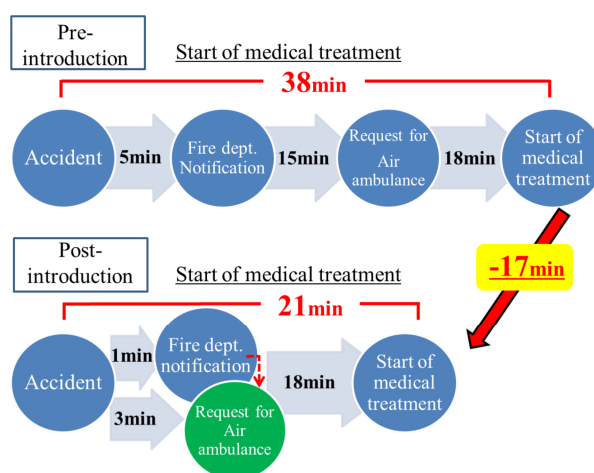


Figure 4. Effect of D-Call Net in reducing treatment start time.

2. OUTLINE OF D-CALL NET SYSTEM

Unlike conventional ACN systems that only transmit vehicle location data to the system operators, D-Call Net calculates the probability of serious or fatal injury to vehicle occupants based on EDR information (such as the collision direction, delta-V (ΔV), seatbelt usage, and whether multiple impacts occurred). This information is sent simultaneously to fire departments and base hospitals operating air ambulances (Fig. 2). The current version of the serious or fatal injury estimation algorithm (Ver. 2015) was created by Toyota Motor Corporation and Nihon University based only on driver seat information from 2.8 million items of accident data in Japan. The same data is also applied to occupants on the passenger side. The recommended threshold for dispatching medical staff to an accident site is set to a 5% probability of serious or fatal injury. After cross-verification with accident conditions in Japan, this threshold was set with the aim of achieving a maximum under-triage (UT) (i.e., when insufficient treatment is provided) rate of 10% and a maximum over-triage (i.e., when more than the minimum necessary care is provided) rate of 61% when the system began operation (Fig. 5) [4].

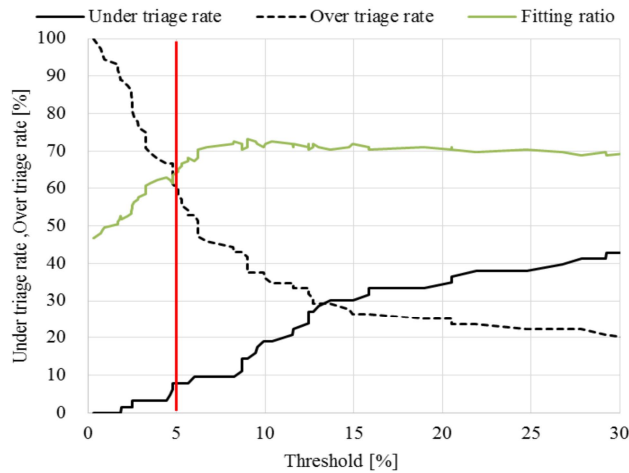


Figure 5. Threshold values of under-triage in Toyota-Nihon University algorithm.

3. APPLICATION TO VEHICLE OCCUPANTS

3.1. Period from Trial to Full-Scale Operation

D-Call Net started trial operations in Japan on November 30, 2015, using vehicles supplied by Honda Motor Co., Ltd. and Toyota Motor Corporation. The system then transitioned to full-scale operation in April 2018. As of the end of January 2019, 374 accidents had been accompanied by notification via D-Call Net (Fig. 6). These real-world accidents were investigated with the cooperation of HELPNET and the Institute for Traffic Accident Research and Data Analysis (ITARDA) to verify the prediction accuracy of D-Call Net.

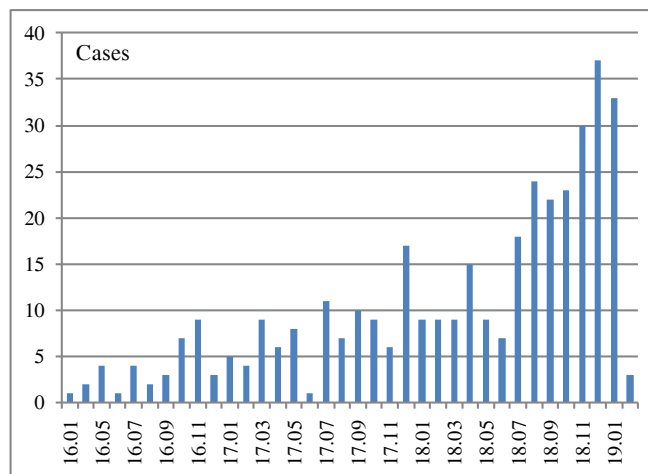


Figure 6. Month-by-month accident occurrence accompanied by D-Call Net notification.

3.2. Evaluation of D-Call Net

The 374 accidents that occurred by the end of January 2019 were analyzed. The results identified an UT rate of 0% and an OT rate of 29%. Furthermore, the correct level of care was predicted in 71% of accidents. These results confirmed that the targets for UT (10% or less) and OT (61% or less) established when the system began operation had been achieved (Figs. 6 and 7).

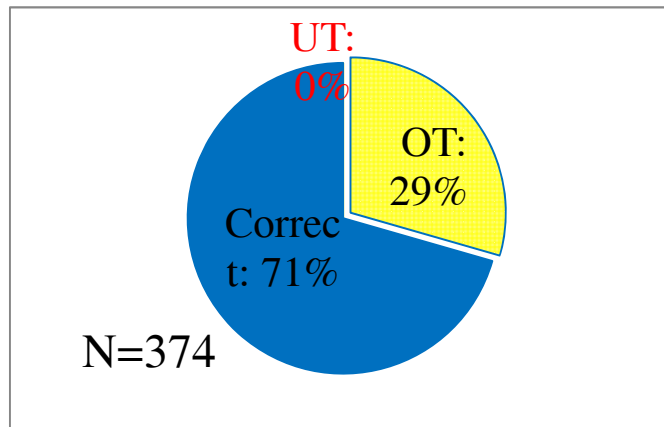


Figure 7. Rate of correct treatment provision by D-Call Net.

A breakdown of the collision types identified 137 frontal collisions, 138 rear-end collisions, and 99 side impact collisions. Over-triage occurred in 54% of the frontal collisions, 13% of the rear-end collisions, and 18% of the side impact collisions, indicating that OT occurs more frequently in frontal collisions (Fig. 8).

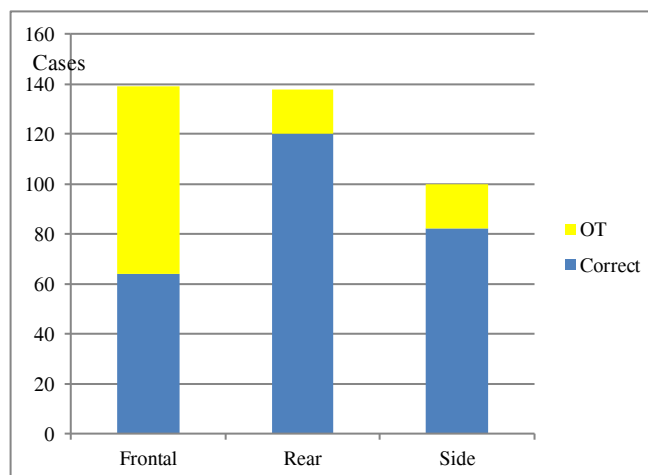


Figure 8. Proportion of OT in each collision type.

Of the 374 accidents, 56 exceeded the threshold for air ambulance dispatch (predicted injury probability of 5%) and required emergency treatment. Of these 56, 17 cases occurred within the time window allowing dispatch of an air ambulance and 39 cases occurred outside this window (Fig. 9). Furthermore, an air ambulance was actually dispatched in only 2 of these 17 cases. The 15 cases in which an air ambulance was not dispatched despite being within the required time window were analyzed. Although hospital transportation was required in these cases, it was determined that dispatch of medical staff to the accident site was not necessary.

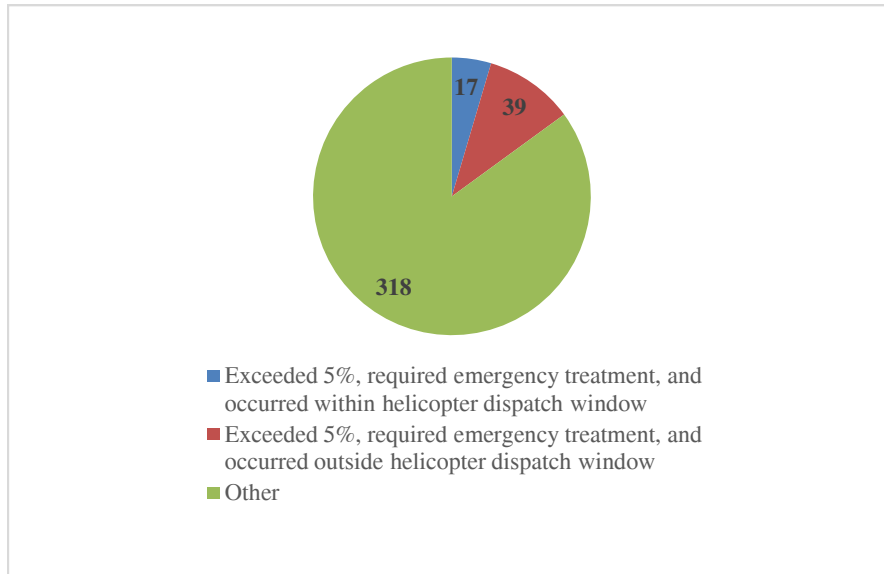


Figure 9. Cases exceeding injury probability of 5% and requiring emergency treatment.

The following section describes the details of these two cases in which an air ambulance was dispatched. Case 1 involved a collision between a mid-sized passenger car (a Toyota Crown) and a mini-vehicle in Chiba prefecture. The driver of the mid-size passenger vehicle suffered whole-body contusions and the driver of the mini-vehicle suffered external injuries (a fractured sternum and fractured right clavicle). Both drivers were taken to a trauma department. This case verified that D-Call Net enables the provision of emergency treatment to occupants of other vehicles in an accident, as well as vehicles actually equipped with the system (Figs. 10 and 11).



Figure 10. Case 1: mid-sized passenger car (Toyota Crown) equipped with D-Call Net.



Figure 11. Case 1: mini-vehicle not equipped with D-Call Net.

The duration before the provision of emergency treatment was as follows. The fire department requested dispatch of an air ambulance 3 minutes after the accident, substantially shortening the time required to reach the accident site. This case highlighted the following issue: Although the helicopter arrived at the accident site as envisioned by the system, it had to wait 17 minutes in the air while the safety of the landing site was secured (Fig. 12).

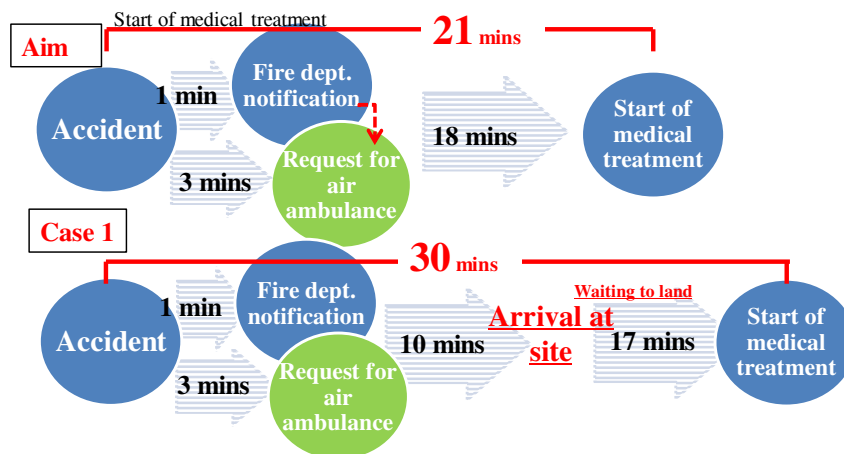


Figure 12. Timetable of case 1.

Case 2 was a collision between a mid-sized SUV (a Lexus RX) and a mini-vehicle pickup truck in Hakodate, Hokkaido (Figs. 13 and 14). Both the driver and passenger seats of the Lexus were occupied. The driver suffered damage to the mesentery tissues and small intestine, and the passenger suffered a burst fracture to the spine. Both were taken to a trauma department. Unfortunately, the occupant of the mini-vehicle pickup truck suffered cardiopulmonary arrest (CPA) before the emergency team arrived and was subsequently confirmed to have passed away. The duration before the provision of emergency treatment was as follows. Dispatch of an air ambulance was requested 11 minutes after the accident, 8 minutes later than the target time of 3 minutes (Fig. 15). This was due to a delay in noticing the D-Call Net information sent to the hospital. This issue must be addressed by, for example, directly sending the information to the mobile telephones of the medical staff.



Figure 13. Case 2: mid-sized SUV equipped with D-Call Net.



Figure 14. Case 2: mini-vehicle pickup truck not equipped with D-Call Net.

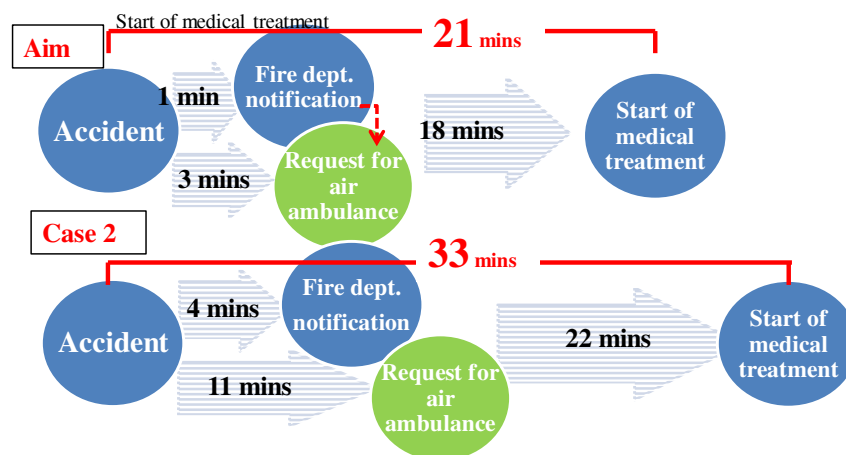


Figure 15. Timetable of case 2.

4. DISCUSSION

The calculated OT rate results for each collision type (Fig. 8) found that OT occurred in frontal collisions more frequently than other collision types. The reasons for this are as follows. The ΔV values of frontal collisions are more widely dispersed at the high end of the ΔV range than side impact and rear-end collisions (Fig. 16). As a result, although the air ambulance dispatch threshold (predicted injury probability of 5%) was exceeded in many frontal collisions, the high OT rate occurred because these accidents actually resulted in less severe injuries.

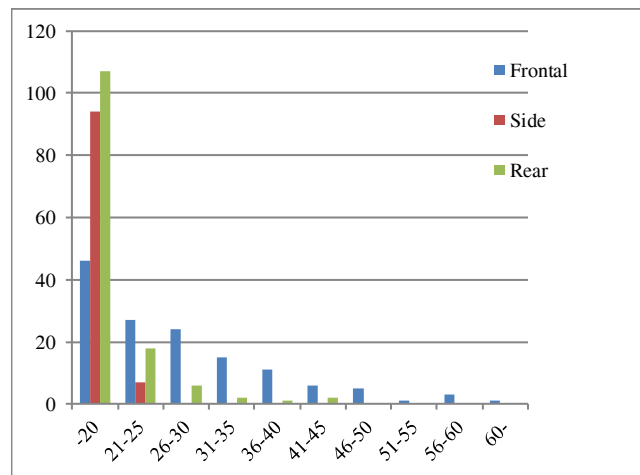


Figure 16. ΔV distribution of each collision type (vertical axis: number of cases, horizontal axis: collision velocity).

Additionally, many of these data cases were acquired from comparatively heavy vehicles (ranging from mid-size passenger cars to large SUVs). However, the current injury prediction algorithm (Ver. 2015) creates a risk curve covering a single category of vehicles ranging from small passenger cars to large SUVs. As a result, it is possible that the severe or fatal injury probability calculated using heavy vehicles may be higher than the real-world injury probability. To verify these suppositions, an algorithm (Ver. 2019) that divides vehicles into more detailed categories was formulated using the most recent year of accident data. Compared to Ver. 2015, which includes two vehicle categories (mini-vehicles and other), Ver. 2019 includes three categories (mini-vehicles, small vehicles, and mid/large vehicles). Figure 17 shows these results. When the OT rate was estimated using the more detailed algorithm (Ver. 2019), the OT rate for frontal collisions fell from 54 to 42%. This shows that the injury prediction accuracy can be improved by adopting more detailed vehicle categories as an algorithm risk factor. In addition to creating more detailed vehicle categories, it is also planned to create risk curves in accordance with the type of collision (frontal, side (near/far), or rear), seating position (driver, front passenger, or rear) to further enhance the accuracy of injury probability prediction.

The results of this verification also identified the following issues.

4.1 Expansion of participating hospitals, including the use of medical vehicles

The results found that 26 of the 108 accidents in which the air ambulance dispatch threshold was exceeded occurred outside the range of participating hospitals with air ambulances, and that 56 cases occurred at nighttime, when air ambulances cannot be dispatched. When D-Call Net started trial operation in November 2015, 9 (out of a total of 53) air ambulances were registered with the system. In the following two-and-a-half years, the number of participating air ambulances has been increased in accordance with HEM-Net (an emergency medical network consisting of helicopters and hospitals). Although the number of participating air ambulances had increased to 45 (approximately 85% of the total) by the end of January 2019, increasing this rate to 100% as quickly as possible is a matter of urgency. Furthermore, since air ambulance operation in Japan is restricted at night, it is extremely important to expand the participation of less-restricted medical road vehicles to help cover accidents that occur after dark.

4.2 Securing of rendezvous points

In case 1, the air ambulance spent 17 minutes above the accident site while the safety of the landing site was secured. To help prevent this situation and bring the medical staff to the patients as quickly as possible, the number of rendezvous points capable of receiving patients quickly and safely must be increased.

Finding ways of addressing these issues will play a major role in further increasing the number of lives saved after traffic accidents. D-Call Net must be used effectively in close cooperation with the relevant government ministries.

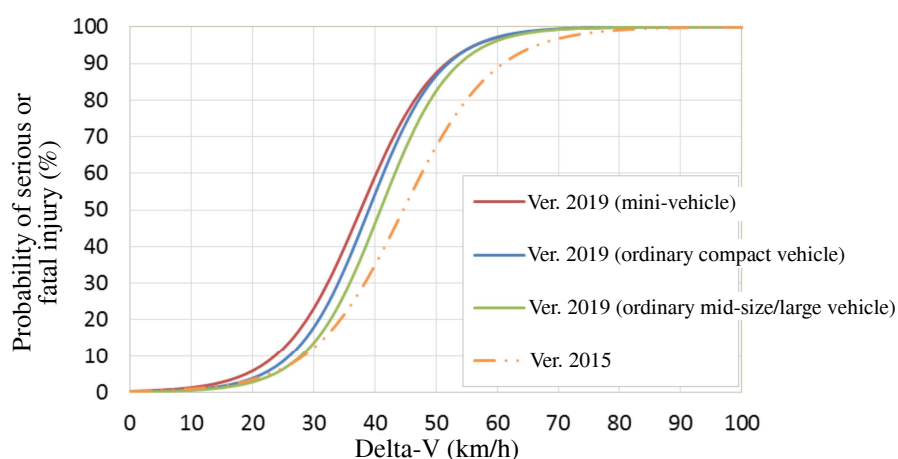


Figure 17. Risk curves for each algorithm version.

6. CONCLUSION

This paper described how the injury prediction accuracy for real-world accidents was verified using vehicles equipped with the D-Call Net system. The results found 374 accidents that used D-Call Net by the end of January 2019. Analysis of these results identified an UT rate of 0% and an OT rate of 29%. The correct level of care was predicted in 71% of these accidents. These results satisfied the targets established when the system

began operation. This paper also described two real-world case studies requiring lifesaving medical treatment, and demonstrated the effectiveness of the D-Call Net system. In the future, it is intended to continue enhancing the serious or fatal injury probability algorithm with the aim of further enhancing the accuracy of injury prediction, and to enlarge the application of D-Call Net in cooperation with the relevant government ministries.

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