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Fatal traffic accidents and forensic medicine

Kazuhiko Kibayashi *, Ryo Shimada, Ken-ichiro Nakao

Department of Legal Medicine, School of Medicine, Tokyo Women's Medical University, 8-1 Kawada-cho, Shinjuku-ku, Tokyo 162-8666, Japan

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ABSTRACT

In the event of a traffic accident fatality, the death is reported as an "unusual death," an inquest is conducted, and, if necessary, a forensic autopsy is performed to prove any causal relationship between the accident and the death, identify the vehicle at fault, and determine the cause of the accident. A forensic autopsy of a traffic accident fatality needs to both determine the cause of death and identify the mechanism of injury, an analytical task that requires observation of three major traffic accident factors: the body, the vehicles involved, and the scene of the accident. Also crucial to determining the cause of death is the process of looking into whether the people involved in the accident had any diseases that might affect their driving performance or were under the influence of alcohol or drugs. In order to reduce the number of people killed in traffic accidents, it will be important to promote joint research uniting forensic medicine, clinical medicine, automotive engineering, and road engineering, take measures to limit the impact of inebriated pedestrians and pedestrians suffering from dementia, and ensure proper screening of alcohol and illegal drug consumption in drivers.

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1. Introduction

Forensic medicine represents one of the medical sciences and plays a prominent role in the investigation of human deaths. Traffic accidents account for the majority of accidental deaths worldwide. The determination of the causes and manners of deaths is an important issue in the investigation of traffic victims. Forensic autopsies of the victims, alcohol and drug analyses of the drivers, and DNA analyses of the specimens help identify causes of death and identify causes of traffic accidents. In this review, we first survey the medico-legal management of traffic accident victims in Japan and then propose ideas for reducing the number of traffic accident fatalities from the perspective of forensic medicine.

2. The relationship between traffic accidents and forensic medicine

Professionals in the field of forensic medicine strive to make fair, scientific medical judgments, advocate for the individuals involved, and help make society a safer and more secure environment when working on legal cases that require medical explanation. Traffic accident fatalities fall into this category, making them an important focal point in the discipline of forensic medicine.

* Corresponding author. Tel./fax: +81 3 5269 7300.
E-mail address: kibayash@research.twmu.ac.jp (K. Kibayashi).

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Table 1
Unusual deaths (reportable deaths).

1. No known natural cause of death
2. External cause of death
    1. Unintentional deaths
        1. Transportation accidents
        2. Exposure to smoke, fire, and/or flames
        3. Falls
        4. Threats to breathing
        5. Drowning and submersion
        6. Poisoning and exposure to noxious substances
        7. Abnormal environment (high or low environmental temperatures, abnormal atmospheric pressure, etc.)
        8. Electrocution and lightning
        9. Natural hazards
        10. Others
    2. Intentional deaths
        1. Suicide
        2. Homicide
3. Medical malpractice

Not all reported cases fall into the above categories.
Reportable deaths are unrelated to the presence and duration of medical care.
Reportable deaths include deaths caused by complications or disabilities with external causes.
The "24 h rule," or deaths that occur within 24 h after hospitalization, does not apply.

Deaths fall into two main groups: "usual deaths" and "unusual deaths". The most common example of a death in the former category would be a person who has an illness (an endogenous disease) and dies in a hospital from the effects of his or her condition—in other words, an "endogenous death" that occurs during the course of medical treatment. In the event of a death that falls into the "unusual" category, meanwhile, Article 21 of the Medical Practitioners Act requires the physician to report the death to the police department with jurisdiction. Although the Medical Practitioners Act does not stipulate exactly what an "unusual death" is, the category covers traffic accident fatalities and all other exogenous deaths (Table 1). A traffic accident is an accident that involves any mode of transportation, be it a car, bicycle, ship, or airplane [15].

All traffic fatalities are reported as unusual deaths and subjected to police inquests. If necessary, a judiciary process called a "forensic autopsy" is then performed to prove whether the victim died of injuries sustained in the accident, identify the vehicle at fault, and determine the cause of the accident. Forensic autopsies come in two types: judicial autopsies, which are performed for criminal deaths in forensic medicine departments at university faculties of medicine and medical schools across the country, and administrative autopsies, which are performed for non-criminal deaths in medical examiner's offices in the 23 wards of Tokyo, Yokohama City, Nagoya City, Osaka City, and Kobe City; in all other areas, autopsies of this second type are performed as administrative autopsy-compliant "autopsies with the consent of the family" in forensic medicine departments. Under the "Act on Investigations, etc., regarding Cause of Death and Identity of Dead Bodies Handled by the Police, etc.," enacted in April 2013, autopsies designed to investigate non-criminal deaths are now performed in forensic medicine departments nationwide (death investigation autopsies). Police and medical examiners select the applicable autopsy type based on the circumstances of the death in question (Fig. 1, Table 2).

3. Physical damage caused by traffic accidents

The main classifications of traffic accident victims—pedestrians, drivers, and passengers (and the less prominent group of victims of accidents involving bicycles or other two-wheeled vehicles)—normally sustain distinctive types of injuries (Table 3). Pedestrian injuries are generally categorized into injuries suffered when the pedestrian makes direct initial contact with a vehicle (primary injuries), injuries suffered when the pedestrian is thrown into direct contact with a vehicle (secondary injuries), and injuries suffered when the pedestrian is thrown to the ground (tertiary injuries). The nature of a pedestrian injury depends on the configuration of the vehicle involved and the speed at which the collision occurs. Whereas a collision between the front bumper of a regular car and a pedestrian tends to result in a bumper primary injury on the pedestrian's legs at roughly the same height as the bumper on the vehicle, for example, a collision with a hoodless, flat-faced "cab-over" vehicle usually creates a primary injury on the person's chest. When working on a hit-and-run case, investigators thus try to identify the vehicle at fault by finding a match between the location of the primary injury and the location of impact on the vehicle. The speed of the collision also affects the nature of the accident: a person will generally end up in front or to the side of the vehicle in a low-speed collision (with the vehicle moving around 20 km/h), tossed

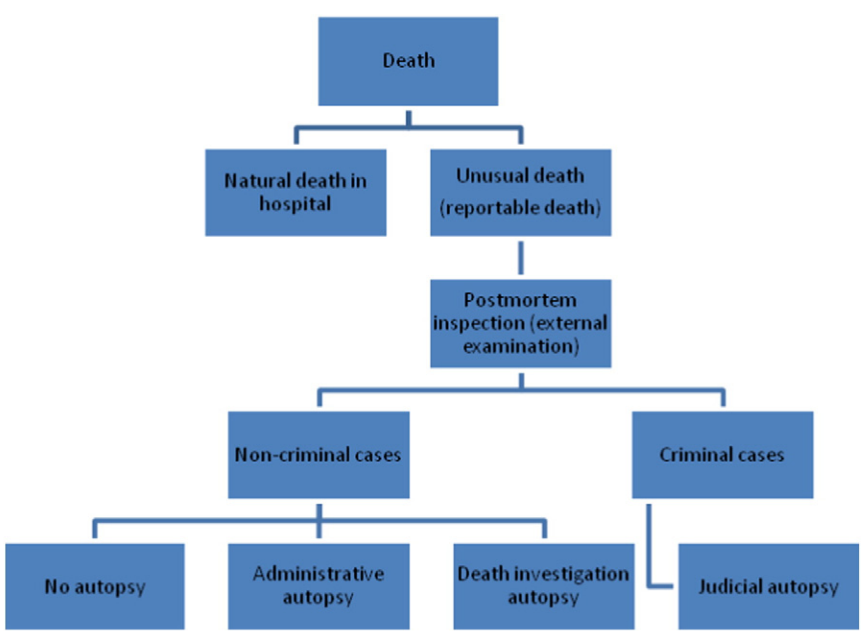

Fig. 1. Medico-legal management of death.

up onto the hood or front windshield of the vehicle in a medium-speed collision (with the vehicle moving 20–60 km/h), and thrown into the air and then brought to the ground in a high-speed collision (with the vehicle moving 60–100 km/h). A low-speed collision often results in the pedestrian being run over by the vehicle involved, while high-speed collisions can cause severe head trauma when the pedestrian hits the road surface [1,3,11,14].

Injuries to the driver and passengers occur if the vehicle collides with another vehicle or a structure off the side of the road, causing parts of the car to bruise the people inside it, if the vehicle tips over, and if people inside are thrown from the vehicle. The driver sometimes sustains a handle injury or suffers a severe injury such as a cardiac rupture if his or her chest smashes into the steering wheel, but a seat belt helps prevent the driver from hitting the steering wheel, ramming into the front windshield, and flying out of the car, which can cause massive trauma. Determining whether the people involved were wearing their seat belts at the time of the accident is thus an integral part of any investigation [2,9]. Seat belts are also vital when airbags deploy; in an accident resulting in airbag deployment, the airbag can expand rapidly into the passenger's chest and cause serious injury. As making clear distinctions between the driver and the passengers helps locate liability for the accident, the driver identification process represents an important diagnostic step in the field of forensic medicine. Linear abrasions caused by seat belt compression—marks known as “seat belt signs”—help identify the seating positions of the occupants.

Investigators working on a forensic autopsy for a traffic fatality have to diagnose the cause of death and determine the mechanism of injury, a process that demands careful observation of the three major factors in a traffic accident: the body, the vehicles involved, and the scene of the accident. In addition to being an integral part of advocating for the individuals involved and preserving peace and order, forensic autopsies also represent a fertile context for uncovering basic research topics that might spur the development of forensic medicine as an academic discipline. From our experiences in forensic autopsies on traffic fatalities, we have identified problems for basic research on the diagnosis and pathological conditions of brain damage and researched methods for verifying hypotheses via animal studies [12,13,17]. Given that brain damage is one of the most common and most severe outcomes of traffic accidents, understanding proper diagnostic procedures and accurate pathological conditions can be tremendously helpful in saving lives.

4. Diseases and driving

There are two basic types of conditions and symptoms that a person can develop while driving a car: diseases that may cause the sudden, unexpected death of the driver and diseases and symptoms that may affect the driving performance of the driver (Table 4). A “sudden, unexpected death” is one in which a healthy individual unexpectedly develops an endogenous disease and dies within 24 h of initial onset. Heart disease, which accounts for the majority of sudden, unexpected deaths, can develop while an individual is driving. Although heart disease can indeed kill a driver, most drivers who develop heart disease while behind the wheel are still capable of moving their shoulder and parking their cars when symptoms first begin to appear; pedestrian and passenger deaths resulting from the sudden onset of heart disease in a driver are thus rare. Diseases and symptoms that may affect the driving performance of a driver, on the other hand, are stipulated in the Order for Enforcement of the Road Traffic Act because they pose potential injury risks to others. Drivers with such conditions are only allowed to drive cars to the extent allowed by their doctors. In the event of a sudden, unexpected death of a driver, investigators often perform an autopsy to differentiate the death from a normal traffic accident fatality. However, diseases and symptoms that may affect the driving performance of a driver seldom become the subjects of forensic medical examinations; although they may help trigger traffic accidents, they almost never actually cause the death of a driver operating a vehicle [3,4,5,6,7,10].

Table 2
Applications of forensic autopsies to traffic accident victims.

1. Hit and run (judicial autopsy)
2. Hit by two or more vehicles (judicial autopsy)
3. Sudden natural death while driving (administrative or judicial autopsy)
4. Identification of driver among occupants (judicial autopsy)
5. Undetermined cause of death (administrative or judicial autopsy)
6. Mechanical problem of the vehicle (judicial autopsy)
7. Exacerbation of pre-existing disease by traffic injuries (administrative or judicial autopsy)
9. Suspected suicide or homicide using a vehicle (judicial autopsy)

Table 3
Injuries of traffic accident victims.

1. Pedestrian
   - Bumper (fender) injury, bonnet or front windshield injury, run-over injury (tire treads, flaying injury), dragging injury
   - Primary injuries: injuries from direct contact with the vehicle
   - Secondary injuries: injuries from contact with other objects of the vehicle
   - Tertiary injuries: injuries from contact with the ground
2. Driver
   - Steering wheel injury, seat belt and airbag injuries
   - Dashboard and front windshield injuries
   - Injuries caused by ejection into the road
   - Whiplash cervical spine injury
   - Braced leg/hip fractures
3. Passenger
   - Seat belt and airbag injuries
   - Dashboard and front windshield injuries
   - Whiplash cervical spine injury
   - Injuries caused by ejection into the road

5. Driving under the influence of alcohol and drugs

The law prohibits driving a motor vehicle under the influence of alcohol or drugs because doing so impairs the driver's judgment and

Table 4
Driver diseases and traffic accidents.

1. Natural diseases that may cause the sudden, unexpected death of drivers while driving
   1. Cardiovascular diseases
      1. Ischemic heart disease
      2. Myocardial infarction
      3. Aortic aneurysm rupture
      4. Aortic dissection
      5. Cardiomyopathy
      6. Myocarditis
   2. Neurological diseases
      1. Rupture of cerebral aneurysm
      2. Hypertensive brain hemorrhage
      3. Brain infarction
   3. Pulmonary diseases
      1. Pulmonary thromboembolism
      2. Bronchial asthma
   4. Digestive tract diseases
      1. Rupture of esophageal varices
   5. Others
      1. Diabetic ketoacidosis
2. Natural diseases and symptoms that may affect the driving performance of a driver
   1. Schizophrenia
   2. Epilepsy
   3. Repeated syncope
   4. Asymptomatic hypoglycemia
   5. Bipolar disorder
   6. Sleep disorder with severe drowsiness
   7. Dementia

Table 5
Blood alcohol concentration (BAC), breath alcohol concentration (BrAC), and degree of intoxication.

	BAC (mg/mL)	BrAC (mg/L)	Degree, signs, and symptoms of intoxication
	<0.1		(Under the detection limit)
Stage 0	0.1–0.5	0.05–0.25	Exhilaration: tipsy feeling
Stage 1	0.5–1.0	0.25–0.5	Weak intoxication: mild inebriation
Stage 2	1.0–1.5	0.5–0.75	Slight intoxication: pleasant, talkative, stimulated mood
Stage 3	1.5–2.5	0.75–1.25	Moderate intoxication: impaired judgment, difficulty walking
Stage 4	2.5–3.5	1.25–1.75	Strong intoxication: slurred speech, clouded consciousness
Stage 5	3.5–4.5	1.75–2.25	Severe intoxication: loss of consciousness, decreased body temperature
Stage 6	>4.5	>2.25	Coma: circulatory failure, respiratory paralysis, death

Large variations of signs and symptoms exist among individuals in each alcohol concentration.

makes it difficult to operate the vehicle normally. Driving under the influence of alcohol corresponds to driving with a blood alcohol content of at least 0.3 mg/mL or a breath alcohol content of at least 0.15 mg/L (under Article 44, Paragraph 3 of the Order for Enforcement of the Road Traffic Act). A person's breath alcohol content is equivalent to roughly 1/2000th of his or her blood alcohol content (Table 5; [8,11]). Blood alcohol content and breath alcohol content have no bearing on "drunk driving," however, which is a state in which a person is unable to drive normally because of alcohol in his or her system. In a normal traffic accident, investigators can determine whether the driver was under the influence of alcohol as long as they can measure the person's breath or blood alcohol content at the time of the accident. In a hit-and-run, though, investigators have little to go on because there is simply no way to obtain alcohol content readings from the driver when or shortly after the incident occurs. Cases where the driver sustains an injury are problematic, too: an ambulance takes the driver to the hospital, making it impossible for investigators to get alcohol content measurements at the time of the accident. In the past, we conducted experimental research to investigate the levels of alcohol and stimulant content in bloodstains at the scenes of accidents and inside the vehicles involved. The results of our investigations showed that alcohol in bloodstains evaporates rapidly and becomes undetectable in a matter of just a few hours. To determine whether an individual was driving drunk, then, it is crucial to collect bloodstains as quickly as possible after the accident and keep the samples in airtight containers. We also learned that, as stimulants remain stable in bloodstains for a prolonged period, investigators can examine bloodstains to make a definitive judgment on whether the individual was intoxicated on stimulants at the time of injury [16].

The law prohibits people from driving vehicles under the influence of drugs that affect driving performance. Thus, forensic autopsies on traffic accident fatalities analyze blood to look for evidence of drug intake prior to death. In our department, we have used gas chromatography–mass spectrometry and high-performance liquid chromatography–tandem mass spectrometry to perform simultaneous qualitative analyses for approximately 300 types of drugs, including banned substances, psychoactive drugs, and sleeping pills, to determine whether the corresponding drivers were under the influence of drugs at the times of their respective accidents (Fig. 2).

6. DNA analysis and traffic accidents

DNA type, or the characteristics of an individual person's unique deoxyribonucleic acid sequences, is represented by the number of repetitions of a particular sequence in a particular locus, the presence of a particular sequence, and other variables. When examining a hit-and-run incident, any match between the victim's DNA type and a DNA type found in bloodstains or tissue fragments from a suspect vehicle is an extremely valuable piece of evidence for identifying the vehicle involved in the incident. ABO blood type is known in most people and used as a target for screening vehicles. We have developed a new method

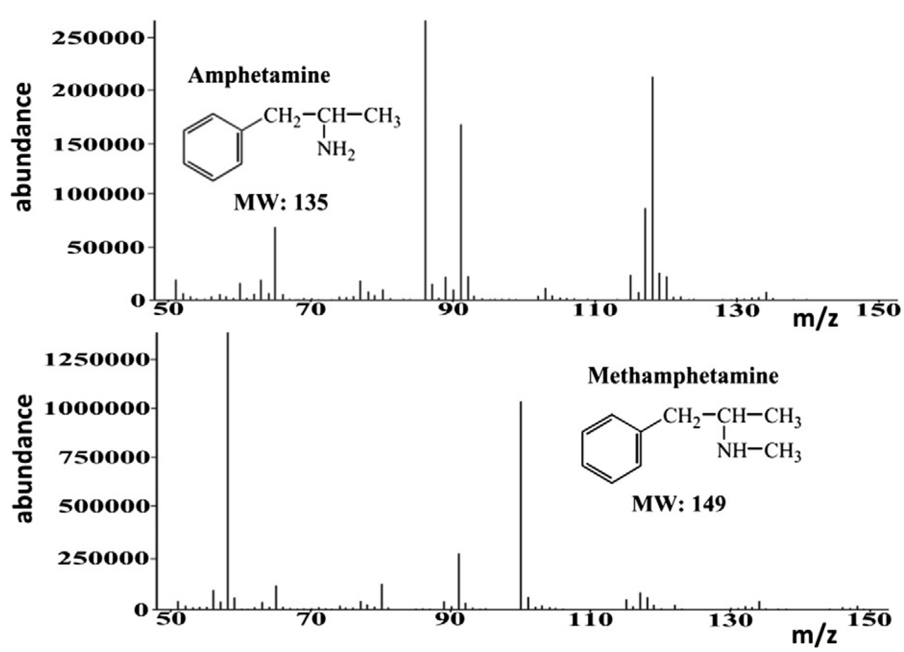

Fig. 2. Gas chromatography–mass spectrometry (GC–MS) analysis of amphetamine and methamphetamine.

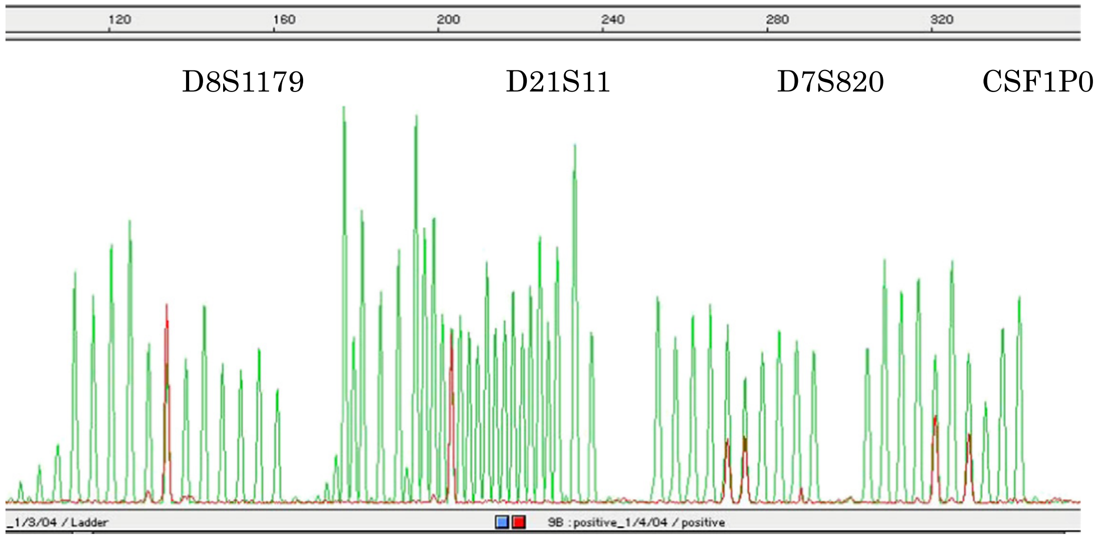

Fig. 3. Electropherograms of DNA typing of four loci of short tandem repeat. Green shows size markers, while red shows sample DNA.

to identify ABO genotypes by using a polymerase chain reaction employing sequence-specific primers [18]. We are currently analyzing a set of 15 loci (D8S1179, D21S11, D7S820, CSF1P0, D3S1358, THO1, D13S317, D16S539, vWA, TPOX, D18S51, D5S818, FGA, D2S1338, and D19S433), which includes the core 13 loci from the US Combined DNA Index (CODIS), for short tandem repeats (Fig. 3). DNA in bloodstains and tissue fragments found on a suspect vehicle can denature due to the effects of ultraviolet rays and bacteria, preventing the accurate detection of short tandem repeats. One of the most effective polymorphic analytical approaches to denatured DNA is the analysis of single nucleotide polymorphisms (SNPs). We have been working in our department settings to devise methods for detecting SNPs in denatured DNA.

7. Ideas for reducing the number of traffic accident fatalities

1) In the field of forensic medicine, examinations of traffic accident fatalities are judicial procedures. However, the insight into causes of death and other medical information that forensic autopsies can reveal is useful in preventing sudden deaths and treating injuries in clinical medicine. Analyses of the mechanisms behind bodily injuries also shed light on the relationships between people, vehicles, and roads, making them valuable resources that experts in the fields of automotive and road engineering can use to improve cars and road environments. Thus, efforts to promote joint research projects that unite forensic medicine, clinical medicine, automotive engineering, and road engineering in exploring traffic accident fatalities will help reduce the number of traffic accident fatalities.
2) Initiatives aimed at preventing traffic accidents involve measures designed to combat drunk driving and mitigate the effects of dementia in drivers, among other strategies. Still, experience has shown that the causes of traffic accidents are often pedestrians in inebriated states or suffering from dementia. Considering that pedestrians frequently sustain severe injuries in traffic accidents, delineating the physical factors affecting pedestrians and devising countermeasures accordingly could bring the number of traffic accident fatalities down in the future.
3) The blood alcohol content levels of trauma patients who were drivers in recent traffic accidents should be measured at medical institutions. If there is a significant lapse of time between an accident and the driver's arrival at the hospital, the medical response team has to take the time to collect two blood samples in order to calculate the driver's blood alcohol content at the time of the accident. Investigators also need to take urine samples from drivers to screen for stimulants, synthetic cannabis, and other illegal drugs that impair driving performance. If these procedures gain traction and become an established part of protocol, it will be possible to deter driving under the influence of alcohol and drugs—two types of behavior that can cause fatal accidents.
4) A hit-and-run incident robs the victim of the opportunity for aid and places a heavy criminal burden on the perpetrator. To prevent hit-and-run incidents, we need to educate drivers about their obligations to aid victims and make a point of the high crime-arrest ratio for hit-and-run.

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