SYSTEMATIC / NARRATIVE REVIEW ARTICLE

Types and risk factors of ambulance accidents: A scoping review

Keng Sheng Chew, PhD[1], Mook Yuang Low, MMed[2]

[1]Faculty of Medicine and Health Sciences, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia, [2]Emergency and Trauma Department, Sarawak General Hospital, Jalan Hospital, Kuching, Sarawak

ABSTRACT

Background: A scoping review was conducted to map out the common research focusses on ambulance accidents, their key findings and some of the major knowledge gaps in this area.

Materials and Methods: Relevant, peer-reviewed, English-language articles on land ambulance accidents were independently searched by the authors using the MEDLINE and CINAHL databases. Anecdotal reports, testimonies and stories in trade or popular magazines and other grey literature were excluded. Articles that do not directly address ambulance accidents were also excluded. Additional articles were identified from the reference lists of the selected articles and from Google search engine.

Results: From an initial yield of 879 articles, 19 articles were included. Most of these articles were published from 2001 – 2005 (5 articles, 26.3%) and 2006 – 2010 (5 articles, 26.3%). Eighteen articles (78.3%) are original articles (18 articles, 78.3%) and another one article is a review article. Most of these articles focused on (1) the types of collisions and (2) the risk factors of ambulance accidents. Nine risk factors were identified to have contributed to ambulance accidents: (1) driving in urban areas (2) driving on dry road (3) the use of lights & sirens (4) the failure to use restraints (5) driving for emergency use (6) back seating (7) at road intersection (8) driver's previous records of accidents and (9) inter-facility transfer. The two most common risk factors studied were (1) the use of lights & sirens and (2) driving at intersection.

Conclusions: Most of the above risk factors can be mapped into three categories of risk factors: task-related factors, vehicle-related factors and environment-related factors. The category of risk factors least studied is the category of driver-related factors.

KEYWORDS:
scoping review, ambulance, emergency vehicle, collision, accident

INTRODUCTION

To achieve quick responses to and from an incident site, ambulances often have to travel at high-speed using lights and sirens (L&S). Unfortunately, high-speed travel and L&S use increases the risk of ambulance accidents.[1-5] Inevitably, this problem must be viewed with utmost seriousness as ambulance is a dedicated vehicle that is supposed to arrest the progression of the illnesses or injuries of patients and to deliver them safely into the healing hands of healthcare providers in hospitals.

Although ambulance accidents can be of grave consequences, there is a paucity of a literature review to systematically analyze prior studies on ambulance accidents. We embarked on a scoping review on peer-reviewed publications related to ambulance accidents. The main purpose of this review is to broadly map out the key research findings on ambulance accidents.[6,7] To conduct this review, the methodological framework by Arksey and O'Malley was adopted.[6] Specifically, the objectives of this review were to identify (1) the common research focusses that have been conducted in the area of ambulance accidents; (2) key findings or trends reported in these studies; (3) major knowledge gaps that could be addressed in future research on ambulance accidents.

MATERIALS AND METHODS

Procedure

The procedure used in this scoping review was based on the 5-step framework by Arksey and O'Malley.[6] These five steps are: (1) defining our research objectives or research questions; (2) identifying the relevant studies; (3) selecting studies to be included based on our inclusion and exclusion criteria; (4) charting and interpreting the data and (5) collating, summarizing, synthesizing and reporting the results.

Eligibility criteria

Only peer-reviewed articles focusing on land ambulance accidents that were published in academic journals were included in this review. Articles such as anecdotal reports, testimonies and stories published in trade or popular magazines as well as in other grey literature were excluded. Articles describing aspects of ambulance safety but do not directly address ambulance accidents; or where the main focus of the articles are not on ambulance accidents, were also excluded. Articles that merely describe air ambulance accidents (but not on land ambulances) were excluded as well. Only English-language articles were included. We did not set a limit on the publication period of our literature search. Search strategy was conducted using the methodology described by Aromataris & Riitano.[8] The keywords and Boolean operators used included the following phrases: ambulance AND crash*, ambulance AND accident*,

This article was accepted: 08 November 2021
Corresponding Author: Keng Sheng Chew
Email: kschew@unimas.my

ambulance AND collision*, emergency vehicle AND crash*, emergency vehicle AND accident* and emergency vehicle AND collision*. The search was conducted using the National Library of Medicine (NLM) MEDLINE database via PubMed search engine and the Cumulative Index of Nursing and Allied Health Literature (CINAHL) database via EBSCOhost search engine. All study designs – quantitative, qualitative and mixed triangulated studies – were included. The reporting was done in compliance with the Preferred Reporting Items for Systematic reviews and Meta-analysis extension for Scoping Reviews (PRISMA-ScR) guideline.[9]

Following the initial generation of records found in MEDLINE and CINAHL databases, titles and abstracts were screened for potentially eligible articles. Both authors (KSC and MYL) independently screened the eligibility of these potential articles. If there was any disagreement between the authors, the authors discussed this together in an attempt to reach a consensus; failure of which, an independent third reviewer would be called in to resolve the disagreement. Additional relevant articles were identified by the authors from the reference lists of the selected articles. All eligible articles identified and agreed upon by both authors were then charted using the PRISMA flow diagram for scoping review process.

Quantitative and qualitative synthesis of the studies were then conducted. For quantitative synthesis, data on countries of origin (where the articles came from), types of articles (i.e., original research, case series, editorial, mortality report, review article, etc.), the journals where the articles were published, the year of publication as well as the objectives and key findings of the articles were extracted. For qualitative synthesis, the full texts of the identified articles were coded using thematic content analysis by labelling the keywords and phrases. After the initial open coding, a second axial coding was performed by re-analyzing these open codes to identify major trends and findings related to ambulance accidents.

RESULTS

The initial literature research yielded 870 articles, with an additional 9 articles obtained via manual search for relevant references within the reference lists as well as from Google search engine. Out of these 879 articles, 31 articles were first removed as these were duplicates. After removing another 789 irrelevant articles and an additional 30 articles that did not fulfill the eligibility criteria of this scoping review (i.e., not peer-reviewed articles published in academic journals), we were left with 29 potentially eligible articles. Another 10 articles were mutually agreed to be removed as they did not directly address ambulance accidents. Eventually, 19 full text articles were identified for inclusion in this review. The PRISMA flow diagram is shown in Figure 1.

Most of these articles were published during the decade from 2001 – 2010, i.e., from the year 2001 – 2005 (5 articles, 26.3%)[2-3,10-12] and from year 2006 – 2010 (5 articles, 26.3%).[4, 13-16] Eighteen articles (78.3%) are original articles (18 articles, 78.3%)[1-5,10-15,17-23] and another one article is a review article.15 Majority of the articles that we analyzed originated from the United States of America (15 out of 19 articles, 78.9%). In brief, most of these articles focused on two key trends of research: (1) the types of collisions and (2) the risk factors of ambulance accidents. The detailed study characteristics of these articles is given in Table I.

1. Types of collisions

Compared to non-ambulance vehicles, ambulances were significantly more likely to be involved in four-way intersection crashes, angled collisions and collisions at traffic signals.[12] This was particularly true in an urban setting, as opposed to a rural setting.[13] Similarly, Sanddal et al reported that ambulance accidents in an urban setting was more likely to have occurred at intersections whereas accidents in a rural setting was more likely to be due to non-intersection rollover collisions.[4] Weiss et al reported that rural ambulance accidents were more likely to be front collisions type whereas urban ambulance accidents were more likely to be rear collisions type.[10]

2. Risk factors of ambulance accidents

Urban versus rural settings

According to Weiss et al, although there were more ambulance accidents in an urban setting compared to a rural setting, the severity of injury in rural accidents were greater than those in urban accidents.[10] This trend of higher incidence of accidents in urban setting compared to rural setting was similarly reported by Sanddal et al,[4] Chiu et al[22] and Missikpode et al.[23] In the Turkish study by Eksi et al,[21] although the authors did not detect significant differences in the overall accident rates in rural versus urban setting, the likelihood of accidents that would result in injuries was significantly higher in rural setting than in urban setting ($p < 0.05$). This was in contrast with Ray et al[13] who reported that urban accidents were more likely to result in injuries compared to rural accidents. Ray et al also found that there was no significant difference in term of the severity of injuries sustained in rural versus urban settings.[13]

Road conditions: Dry road versus wet road

Ironically, out of the 6 articles that examined the association between road conditions and ambulance accidents, 5 articles reported that more accidents occurred on dry road condition than on wet road condition.[1,3,10,13,18] The only article that reported no significant difference was Missikpode et al.[23]

Using L&S vs not using L&S

The use of L&S to save travel time is arguably one of the most extensively researched factors of ambulance response.15 L&S use had been shown to increase (1) the total number of ambulance accidents[1,4-5] and (2) the risk of injuries in ambulance accidents.[3,17]

Watanabe et al categorized ambulance accidents into 2 phases, i.e., (1) "response to the scene" and (2) "transport from the scene" phase.5 In both phases, the rates of ambulance accidents were significantly higher when L&S was used. Specifically, in the "response to the scene" phase, the accident rate was 5.4 per 100,000 trips with L&S use vs 4.6 per 100,000 trips without L&S use (adjusted odds ratio of 1.5; 95% CI 1.2 to 1.9). In the "transport from the scene" phase, the accident rate was 17.1 of 100,000 trips with L&S use

Table I: Study Characteristics of the Identified Studies

Study characteristics (N = 19)	Count (%)	References
Publication years		
1986 – 1990	1 (5.3)	17
1991 – 1995	2 (10.5)	1, 18
1996 – 2000	1 (5.3)	19
2001 – 2005	5 (26.3)	2, 3, 10-12
2006 – 2010	5 (26.3)	4, 13-16
2011 – 2015	2 (10.5)	20-21
2016 – 2020	3 (15.8)	5, 22-23
Country of origin		
United States	15 (78.9)	1-5, 10-13, 15-17-19, 23
Turkey	2 (10.5)	20-21
United Kingdom	1 (5.3)	14
Taiwan	1 (5.3)	22
Types of articles		
Original article	18 (94.7)	1-5, 10-14, 16-17-23
Review article	1 (5.3)	15
Journals		
Prehosp Disaster Med	4 (21.1)	1, 16, 18-19
Perhosp Emerg Care	5 (26.3)	2-3, 12-13, 15
Ann Emerg Med	1 (5.3)	5
Accid Anal Prev	2 (10.5)	11,23
Emerg Med J	1 (5.3)	14
Am J Emerg Med	1 (5.3)	10
JAMA	1 (5.3)	17
J Forensic Leg Med	1 (5.3)	20
Emerg Med Int	1 (5.3)	4
J Formos Med Assoc	1 (5.3)	22
Turk J Emerg Med	1 (5.3)	21
Risk factors for ambulance accidents		
Urban vs Rural settings		4, 10, 13, 21-23
Dry road vs wet road		1,3,10, 13, 18, 23
Using light & sirens vs not using light & sirens		1, 3-5, 15, 17
Restrained vs unrestrained passengers		10-11, 17
Emergency use vs non-emergency use		2, 11, 18, 23
Front seat passenger vs back seat passenger		2, 11
At intersection vs not at intersection		2-4, 10, 12-13, 17-18, 22
Previous records of accidents vs no previous records of accidents		2, 11,18, 23
Inter-facilities transfer vs primary response to site		20

versus 7.0 of 100,000 trips without L&S use (adjusted odds ratio 2.9; 95% CI 2.2 to 3.9).

Restrained vs unrestrained passengers

According to Auerbach et al[17], the failure to use restraint is the most important factor associated with injuries in ambulance accidents (relative risk is 0.098 when restraint was used compared to when it was not used; p = 0.007).[17] This risk of accidents with injuries among unrestrained passengers was even more significant in a rural setting compared to an urban setting.[10] Restrained passengers were significantly less likely to suffer death or seriously injured than unrestrained passengers.[11]

Emergency use vs non-emergency use of ambulances

With regards to the use of ambulance for emergency purposes (as opposed to, for non-emergency purposes), the results are equivocal: 2 studies reported that emergency use increased the risk of ambulance accidents[2,18] whilst another 2 studies did not increase the risk of ambulance accidents.[11,23] In fact, Becker et al reported that, ironically, non-emergency uses appeared to be more likely than emergency use to result in fatal accidents (relative risk ratio = 2.62; p< 0.05) or in severe injuries (relative risk ratio = 1.69; p< 0.0001).[11]

Types of seating: Front seat passenger vs back seat passenger

Two articles described the effect of front seating vs back seating on ambulance accident.[2,11] In both articles, it was reported that back seat passengers were more likely to be injured or killed than those in the front seat.

At intersection vs not at intersection

Out of the 9 articles that reported on the effect of "at intersection", 8 articles reported that there were more ambulance accidents occurred at intersections[2-4,12-13,17-18, 22,] particularly in an urban setting.[4,13] Only Weiss et al reported that there was no difference between the number of ambulance accidents at an intersection vs when not at an intersection.[10] Custalow et al[3] reported that ambulance accidents that occurred at an intersection was highly predictive of an injury or fatality.

Previous driver's records of accidents

Two articles reported on the impact of driver's previous records of ambulance accidents on future accidents.[2-3] In both of these articles, it was found that many ambulance drivers who were involved in fatal accidents had poor driving records.

Table II: Detailed Descriptions of Key Findings of Identified Articles

	Author(s)	Year	Objectives/aims	Data source	Key Findings and conclusion
1.	Auerbach PS, Morris JA Jr, Phillips JB Jr, Redlinger SR, Vaughn WK.	1987	to analyze the epidemiology of ambulance crash in the state of Tennessee from 1 Jan 1983 to 1 July 1986.	Ambulance crash incidents reported to the Division of Emergency Medical Services, Tennessee Department of Health and Environment (TDHE-DEMS), Nashville	Twenty-nine accidents (28.4%) contributed to a total of 65 injured victims, with one death. The three variables most strongly associated with the probability of a collision resulting in an injury were (1) use of a passenger restraint device, darkness and occurrence at an intersection. The variable most strongly associated with the probability of an injury-accident was failure to use the passenger restraint device (P = 0.007; relative risk is 0.098 when restraint was used compared to when not used). Darkness (P = .08; relative [high] risk, 3.05) and occurrence at an intersection (P = 0.13; relative [high] risk, 2.25) were variables showing increased risk, but were not statistically significant.
2.	Pirrallo RG, Swor RA.	1994	to analyze the characteristics of fatal ambulance crashes to assist emergency medical services (ems) directors in objectively developing their ems system's policy governing ambulance operations.	Fatal Accident Reporting System (FARS) from 1987 to 1990.	Seventy-five fatal crashes (69%) occurred during EU and 34 fatal crashes (31%) occurred during NEU, the number of fatal EU crashes also lessened while the number of fatal NEU crashes increased progressively (p =0.016). More fatal ambulance crashes occurred during the afternoon (37.6%) than during any other time interval. The lowest number of ambulance crashes resulting in fatalities occurred late at night (15.6%). The percentage of EU crashes was elevated between 1200 h and 1800 h (44.0%), whereas the largest percentage of NEU crashes took place between 0000 h and 0600 h (32.4%). These differences are statistically different (p = 0.009). The increased number of EU crashes during daylight hours could be surmised by the larger volume of cardiac arrest ambulance calls during the daytime. The increased number of NEU crashes that occur during decreased light conditions may be inferred by the relative reduced visibility of the ambulance when lights and siren are not used.
3.	Saunders CE, Heye CJ.	1994	To characterize ambulance collisions and assess the risk of traveling with lights and siren in an urban emergency response setting	Data of all consecutive ambulance collisions of the Paramedic Division of the San Francisco Department of Public Health during a 27-month period.	Overall collision rate for lights and siren (LS) travel was higher than that for non-lights and siren travel, although the difference was not statistically significant (45.9 collisions per 100,000 LS patient travels, 95% CI 29.7-62.1, versus 27.0/100,000 for non-LS travel, 95%CI 18.3-35.7). The rates of resulting injuries displayed a statistically significant difference (22.2 injuries per 100,000 LS patient travel, 95% CI 11.0-33.5, versus 1.5/100,000 for non-LS travel, 95% CI -0.6 - 3.5). Majority of collisions (60.0%) occurred during patient-related travel. Majority of collisions were due to inattention, failure of on-coming traffic to yield, or unsafe parking; unsafe speed was an infrequent cause. Most crashes occurred during daylight, in dry weather, and involved another vehicle.
4.	Biggers WA Jr, Zachariah BS, Pepe PE.	1996	to define the incidence and severity of, and to identify any contributing factors to EMVCs in a large urban system (Houston)	Data from the Fire Academy of the Houston Fire Department for year 1993	Of the 86 EMVCs identified, 74 (86%) files were complete and available for evaluation. Major collisions, determined according to injuries or vehicular damage, accounted for 10.8% of all EMVCs. The majority of collisions (85.1%) occurred at some site other than an intersection. There was no statistical association between occurrence at an intersection and severity, day versus night, weekend versus weekday, presence or absence of precipitation, or use of WL & S versus severity of collision. Drivers with a history of previous EMVCs were involved in 33% of all collisions.

cont..... pg 64

cont from..... pg 63

Table II: Detailed Descriptions of Key Findings of Identified Articles

	Author(s)	Year	Objectives/aims	Data source	Key Findings and conclusion
5.	Kahn CA, Pirrallo RG, Kuhn EM.	2001	To describe fatal ambulance crash characteristics, identifying those that differentiate emergency and nonemergency use crashes	All fatal ambulance crashes on U.S. public roadways reported to the Fatality Analysis Reporting System (FARS) database from 1987 to 1997	Three hundred thirty-nine ambulance crashes resulting in 405 fatalities and 838 injuries. Most crashes (202/339 or 60%) and fatalities (233/405 or 58%) occurred during emergency use. Emergency use was defined as use of lights and siren while traveling. These crashes during emergency use occurred significantly more often at intersections ($p < 0.001$), at an angle ($p < 0.001$), with another vehicle ($p < 0.001$). The most serious and fatal injuries occurred in the rear (OR 2.7, as opposed to front); and to improperly restrained occupants (OR 2.5; as opposed to those properly restrained). 41% of these ambulance drivers had records of previous crashes, suspensions, and/or motor vehicle citations suggesting that previous crash history maybe an indicator or predictor of another crash.
6.	Weiss SJ, Ellis R, Ernst AA, Land RF, Garza A.	2001	to compare urban and rural ambulance crashes in the state of Tennessee	Data from the mandatory reporting forms for all ambulance accidents in the state of Tennessee	Although more crashes occurred in urban setting compared to rural, the rate of injuries sustained were significantly lower in urban crashes compared to rural crashes (OR = 0. 49, 95% CI = 0.24 to 0.98) and fewer of these urban crashes were considered "severe" compared to rural type. The postulation by the authors was that rural travel involved longer distance across the county, travelling at higher speed and frequently with lack of restraints. No significant difference in terms of the number of crashes at intersection in both types of crashes (urban 32%, rural 22%, $p = 0.14$).
7.	Becker LR, Zaloshnja E, Levick N, Li G, Miller TR.	2003	to address the impacts of emergency vehicle (ambulances, police cars and fire trucks) occupant seating position, restraint use and vehicle response status on injuries and fatalities.	Merged data from Fatality Analysis Reporting System (FARS) and the General Estimates System (GES) from 1988 through 1997.	Restrained ambulance occupants involved in a crash were significantly less likely to be killed (3.77 times lower risk, $p < 0.009$) or seriously injured (6.49 times lower risk, $p < 0.0001$) times lower than unrestrained occupants. Ambulance rear occupants were significantly more likely to be killed than front-seat occupants (5.32 times higher risk than for front-seat occupants, $p < 0.0001$). Relative to police cars and fire trucks, ambulances experienced the highest percentage of fatal crashes where occupants are killed and the highest percentage of crashes where occupants are injured.
8.	Custalow CB, Gravitz CS.	2004	to identify factors associated with ambulance accidents that are potentially amenable to preventive intervention	Paramedic Division of the Denver Health and Hospital Authority (DHHA) from 1989 - 1997	Using multiple logistic regression, T-bone mechanism, collision at an intersection, and alcohol intoxication of the civilian drivers were significant predictors of collisions resulting in injury (odds ratios of 29.7, 4.3 and 6.1, respectively, $p<0.05$. Although only 75% of the division's responses are run with warning lights and sirens (WLS), a disproportionate 91% of response mode collisions were during a WLS response.
9.	Ray AF, Kupas DF.	2005	To describe the characteristics and associated occupant injuries of ambulance accidents as compared with accidents involving similar-sized vehicles.	Motor vehicle accidents data collected by the Pennsylvania Department of Transportation from 1997 to 2001	Ambulance accidents occurred with increased frequency on evenings (19% vs 10% respectively from 1801 - 0000 hours) and weekends (15% vs 8% respectively on Saturdays; and 9% vs 4% respectively on Sundays). Ambulances were more likely to be involved in four-way intersection crashes (43% vs. 23%, $p = 0.001$), angled collisions (45% vs. 29%, $p = 0.001$), and collisions at traffic signals (37% vs. 18%, $p = 0.001$). More people were involved in ambulance accidents ($p = 0.001$), with 84% of ambulance accidents involving three or more people and 33% involving five or more people. Injuries were reported in more ambulance accidents (76% vs. 61%, $p = 0.001$).

cont..... pg 65

cont from..... pg 64

Table II: Detailed Descriptions of Key Findings of Identified Articles

	Author(s)	Year	Objectives/aims	Data source	Key Findings and conclusion
10.	Ray AM, Kupas DF.	2007	To describe and compare the characteristics of, and associated injuries caused by, ambulance crashes that occur in rural versus urban areas.	Data from Pennsylvania Crash Outcome Data Evaluation System database from 1997 to 2001	Operator error was the most common cause for both types of crashes (75% for rural; 93% for urban), whereas environmental factors (e.g. darkness, snowy conditions) were more prevalent in rural crashes (25% vs. 7%). Urban crashes were more likely to involve angled collisions with other vehicles (54% vs. 19%), intersections (67% vs. 26%), and occured at a stop sign (53% vs, 14%). Rural crashes often involved striking a fixed object (33% vs. 7%). In terms of the severity of injuries sustained, majority (>50%) of the injuries sustained appeared to be minor in both types of crashes.
11.	Lutman D, Montgomery M, Ramnarayan P, Petros A.	2008	to determine how many deaths and injuries were caused by ambulances and aeromedical accidents	Data for ambulance accidents were obtained from the Department for Transport, Road Statistics whereas data for air ambulance accidents were obtained from Civil Aviation Authority, Aviation Safety Review from 1999 to 2004	The authors concluded that although the numbers of fatalities per year remained small, each death should be considered as a disaster and every attempt needs to be made to reduce the incidence to zero.
12.	Sanddal ND, Albert S, Hansen JD, Kupas DF.	2008	to review the literature and discuss the implications for rural EMS agencies and personnel, and to provide a sample policy or protocol that could be adapted for use in most communities.	literature indexed in MEDLINE (1996–2007). A secondary search was conducted using Academic Search Premier, Comprehensive Index of Nursing, and Allied Health Literature. MeSH search terms used in MEDLINE included "ambulance"; "accident", "traffic"; "emergency medical technician"; "occupational health"; and "rural".	28 out of 32 literature were included. The authors categorized their literature review into 4 sub-headings: 1) description of the problem; 2) safety issues; 3) lights and siren use and 4) legal and ethical risks. The authors concluded that driving an ambulance is a dangerous process. A key factor in ambulance crashes is he use of warning lights and sirens. The authors also highlighted the reluctance of emergency care providers to wear safety restraints in ambulance.
13.	Studnek JR, Fernandez AR.	2008	to explore the hypothesis that demographic and work-related characteristics are associated with involvement in ambulance crashes	2004 Longitudinal Emergency Medical Technician Attributes and Demographics Study	A total of 111 (8.6%) of participants reported being involved in an ambulance crash within the past 12 months. On average, the EMS professionals involved in an ambulance crash were younger than those reporting no involvement in a crash 31.0 ±8.2 vs. 34.8 ±10.0 respectively ($p < 0.01$). Specifically, 14.9% of EMS professionals who reported sleep problems were involved in a crash as compared to only 7.5% of those who did not have sleep problems. Results from this analysis suggest age and sleep problems are associated with involvement in an ambulance crash.
14.	Sanddal TL, Sanddal ND, Ward N, Stanley L.	2010	to analyze the 466 ambulance crashes from May 1, 2007 to April 30, 2009, reported in EMSNetwork, which is a site collecting articles from newspapers and other popular press sources	All ambulance crashes published in newspapers and other popular press and complied on the EMSNetwork website occurring between May 1, 2007 and April 30, 2009 were printed	Seventy-nine (79) crashes resulted in fatalities to persons inside or outside of the ambulance. As a result of the 79 fatal crashes, a total of 99 persons died. Intersections were the most common location (196 (42%) of 466 total) noted for the crash. In 145 cases, the ambulance was responding to an emergency. Out of these 139 cases where the utility of lights and siren were noted, 111 (80%) of these cases had used lights and ambulance at the time of crash. More crashes occurred in urban setting (382 cases, 82%) than in rural setting (84 cases, 18%).

cont..... pg 66

cont from..... pg 65

Table II: Detailed Descriptions of Key Findings of Identified Articles

	Author(s)	Year	Objectives/aims	Data source	Key Findings and conclusion
15.	Ersoy G, Ersoy O, Yuksekbas O, Kurnaz G, Akyildiz EU, Ekemen S.	2012	to investigate traumatic consequences of ambulance accident on patients	Data were collected from the reports issued by the First Board of Council of Forensic Medicine (CFM)	15 cases died on the day of the accident. Skin injuries at head (8 cases) and legs (6 cases) were most common traumatic lesions. In total, only 6 deaths were found to be directly related to ambulance accident. Death of patient after ambulance accidents may not be associated easily to the accident. This is because death of patients after the ambulance accidents could be directly due to these accidents or the medical conditions which cause these patients to be transported in ambulances in the first place. This is not surprising in that most of the patients had a life-threatening condition, severe trauma or chronic disease at the terminal stage. Even if they had not had an ambulance accident, they had a high risk of mortality.
16.	Eksi A, Celikli S, Catak I.	2015	to evaluate the effects of the institutional structural changes and legislative framework on the number of ambulance accidents in Turkey. Institutional changes in the management of ambulance services in Turkey at the time of publication were (1) changing from employing ambulance drivers whose only role and responsibility was to drive ambulances (staffed together with doctors and nurses) to employing paramedics and EMTs to drive the ambulances; (2) the increased number of female drivers; and (3) decreasing the level of overall driving experience of these newly appointed paramedic/EMT drivers.	(1) ambulance accident data from the Ministry of the Interior and (2) data on ambulance numbers was obtained from the Ministry of Health	The effects of changes in the system were all found to have no significant effect on the increased number of ambulance accidents. The number of ambulance accidents increased by 42.5% over five years (2009 - 2013), whereas the area of coverage increased by 57.3% during the same period. The rate of EMS personnel experiencing ambulance accidents was 69.4%.
17.	Chiu PW, Lin CH, Wu CL, Fang PH, Lu CH, Hsu HC, Chi CH.	2018	to analyze the characteristics of ambulance accidents in Taiwan	Ambulance accidents data from the National Fire Agency of Taiwan	715 ambulance accidents resulting in 1852 victims (8 deaths within 24 h and 1844 injured patients; fatality rate 8/1852 = 0.4%). Compared to overall traffic accidents, ambulance accidents were 1.7 times more likely to lead to death and 1.9 times more likely to lead to injuries among patients. On average, there was one ambulance accident for every 8598 ambulance runs. Among the 715 ambulance accidents, 8 (1.1%) ambulance accidents were fatal and 707 (98.9%) were nonfatal. All 8 fatalities were associated with motorcycles. The urban areas were significantly higher than the rural areas in the annual number of ambulance accidents (14.2 ± 7.3 [7.0–26.7] versus 3.1 ± 1.9 [0.5–8.4], p = 0.013), the number of ambulance accident-associated fatalities per year (0.2 ± 0.2 [0.0–0.7] versus 0.1 ± 0.1 [0.0–0.2], p = 0.022), and the annual number of injured patients (who needed urgent hospital visits) in ambulance accidents (19.4 ± 7.3 [10.5–30.9] versus 5.2 ± 3.8 [0.9–15.3], p < 0.001). This 24-h ambulance accident fatality rate in Taiwan (0.4%) is almost four times of the fatality rate in the United States (0.1%) as reported in previous studies. All fatalities and almost half of the injuries in ambulance accidents were associated with motorcycles.

cont..... pg 67

cont from..... pg 66

Table II: Detailed Descriptions of Key Findings of Identified Articles

	Author(s)	Year	Objectives/aims	Data source	Key Findings and conclusion
18.	Missikpode C, Peek-Asa C, Young T, Hamann C.	2018	to estimate relative risks for emergency vehicle crashes driving in emergency mode compared with non-emergency mode, including police, ambulance and fire vehicles	Iowa Crash Database for the period of 2005 through 2013.	Police vehicles had 1.28 (95% CI = 1.07–1.53) times the risk for crashing when in emergency mode. Ambulances and fire vehicles had no increase in crash risk while driving in emergency mode (OR = 1.08; 95% CI = 0.74 – 1.58). Female drivers and driver age under 30 were associated with an increased crash risk for crashing in both the police and ambulance/fire model.
19.	Watanabe BL, Patterson GS, Kempema JM, Magallanes O, Brown LH.	2019	to compare crash rates between ambulance with versus without lights and sirens	transporting patients from an emergency scene	Response phase crash rate was 4.6 of 100,000 without lights and sirens and 5.4 of 100,000 with lights and sirens (AOR 1.5; 95% CI 1.2 to 1.9). Response phase means the ambulance's response to the scene whereas transport phase refers to the phase where the ambulance transport the victim back to the medical center or hospital. For the transport phase, the crash rate was 7.0 of 100,000 without lights and sirens and 17.1 of 100,000 with lights and sirens (AOR 2.9; 95% CI 2.2 to 3.9). Ambulance use of lights and sirens is associated with increased risk of ambulance crashes. The association is greatest during the transport phase. EMS providers should weigh these risks against any potential time savings associated with lights and sirens use.

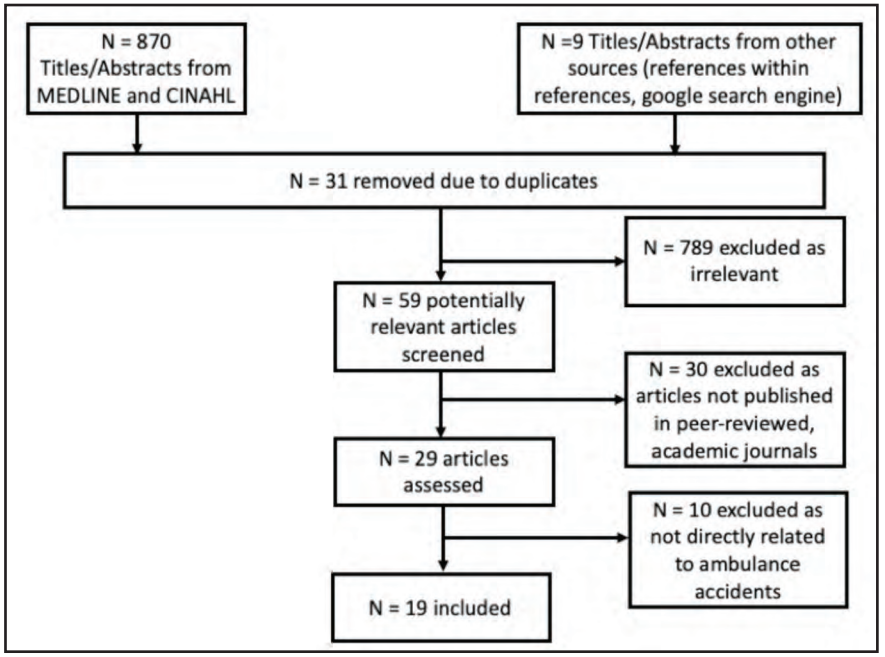

Fig. 1: Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) Flow Diagram for Scoping Review.

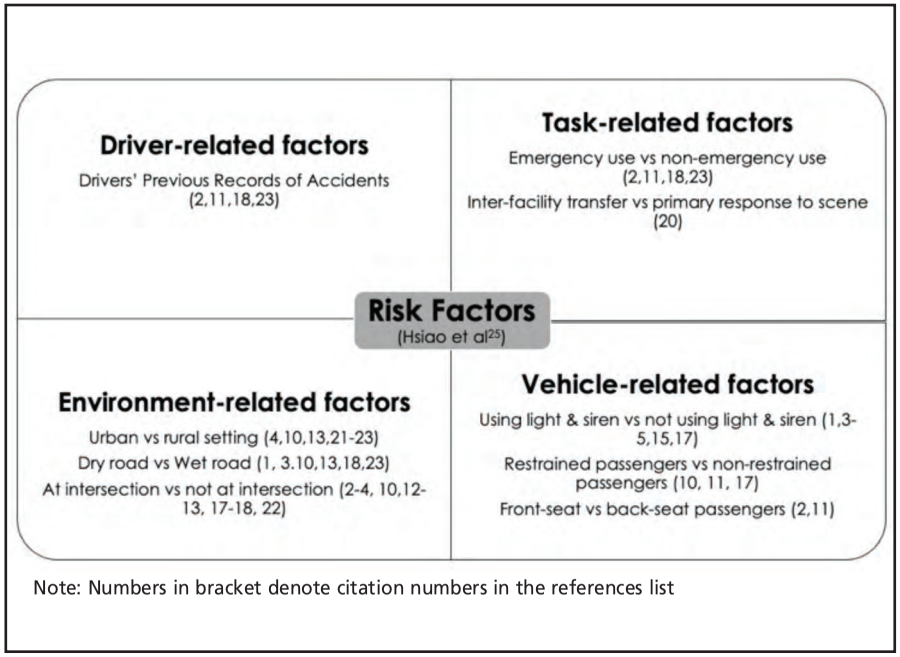

Fig. 2: Framework of Risk Factors for Ambulance Accidents.

Type of transfer- Interfacility vs primary response

Ersoy et al reported that only 6 ambulance accident cases were due to transportation to a healthcare facility (primary response) compared to 15 cases (71%) that were due to transportation from one healthcare facility to another (inter-facility transfer).[20]

The data on the study characteristics (i.e., the country of origin, types of articles, the journals where these articles were published, year of publication, objectives as well as the risk factors for ambulance accidents reported in these articles) are tabulated in Table I. The detailed descriptions of the key findings of these articles are given in Table II.

DISCUSSION

The two most common research areas on ambulance accidents identified in this scoping review are the types of collisions and the risk factors for ambulance accidents. With regards to risk factors, we identified 9 risk factors that contributed to ambulance accidents: (1) driving in urban settings (2) driving on dry roads (3) the use of L&S (4) the failure to use restraints (5) driving for emergency use (6) back seating (7) at road intersection (8) driver's previous records of accidents and (9) inter-facility transfer.

Out of these 9 risk factors, the two most studied risk factors are the use of L&S and when driving at road intersection. L&S is often used by ambulances to herald its arrival and to request the right-of-way from other drivers. To be effective however, the siren sound must be of sufficient loudness and frequency in order to overcome the competing masking noises generated from the road, vehicle engines, sound systems, ventilation system sound, sound insulation system, etc.[24] But with this degree of loudness, it may also limit the ambulance driver's ability to pick up important auditory signal from the radio system or from surrounding vehicles.[24-25] This may predispose the vehicle to ambulance accidents. L&S can also have a number of adverse effects to the surrounding vehicles. For example, the strobe light can trigger a number of bodily reactions such as unusual feeling, involuntary twitch, impede the vision of other drivers, induce the distractions of drivers[25] and can even produce a "wake effect".[26] "Wake effect" refers to the phenomenon of accidents involving surrounding vehicles caused by the passage of an ambulance with L&S when the other vehicles are pulling to the side of the road, running through red lights, slowing down, etc.[26] More importantly, most studies have shown that although the time saved with the use of L&S may be statistically significant, they were often not clinically significant.[27-32] For example, one study showed that even with the amount of time saved using L&S, none of the patients were able to receive any time-critical interventions within that short period of time.[29] For this reason, it is argued that the use of L&S is often unwarranted except in the most pressing clinical circumstances.

In the study by Watanabe et al[5], although L&S use was associated with increased rates of ambulance accidents in both response and transport phases compared to when no L&S was used, this increase was more significant during the transport phase. The authors hypothesized that during the "response to the scene" phase, two healthcare staff were typically seated in the front compartment of the ambulance and they shared the cognitive load required to operate the ambulance (e.g., using the radio, activating the siren, watching for traffic risks). But during "transport from the scene", only the driver was typically seated alone in the front compartment. The other staff would be attending to the victim in the ambulance cabin.[5] The increased cognitive load imposed on the driver predisposes him or her to accidents.

Indeed, ambulance driving is a cognitively demanding task particularly when the driver is driving at high speed. It can also be a highly stressful task[33], as the driver often has to attend to secondary tasks simultaneously such as engaging in radio communication and identifying the victim's location. Often, these secondary tasks may even require eyes to be taken off the road[34] resulting in inattentional driving. The demands for secondary tasks and "eyes-off-road" can significantly delay a driver's response time by 16% and 29% respectively.[34]

Stress by itself has also been shown to result in a surge of adrenaline. Witzel et al had demonstrated increased levels of cortisol and other adrenocortotropic hormones in ambulance drivers during emergency driving compared to during non-emergency driving.[35] This sympathetic response results in more aggressive and risk-taking behaviors among the drivers. The problem of cognitive overload is further compounded when an ambulance driver approaches the dilemma zone of a road intersection.[25] Dilemma zone is the stretch of road before an intersection traffic light where an ambulance driver is faced with the dilemma of whether to apply brake or to run through the red traffic light without stopping.[36] Should an ambulance driver decide to run the red traffic light without stopping, he or she may also face the challenge of other potential red-light runners coming from another direction. This is because the decision to run through the red light is predicated on the trust that other road users would comply with traffic rules and give way to the ambulance. But when this trust is breached, unpredictable traffic conflicts and accident risk may result. On the other hand, should the ambulance driver decide to abruptly apply brake to the fast-moving ambulance, this may create a sudden conflict with the vehicles following behind, leading to risk of rear-end collisions.[37] The ambulance driver often faces a surge of high cognitive load, split-second decisions that must be made at the dilemma zone.[38]

According to a framework on ambulance accidents developed by Hsiao et al[25], risk factors for ambulance accidents can be divided into four broad categories, i.e., (1) driver-related factors (e.g. individual differences, driver experience and driver behavior); (2) task-related factors (e.g. time pressure, secondary-task demands, long shift hours, driving under emotions); (3) vehicle-related factors (e.g. vehicle characteristics, in-vehicle equipment, conspicuity, warning signals) and (4) environment-related factors (e.g. at intersection, traffic signals, speed, light conditions, weather). Using this framework to map out the 9 risk factors we have identified in this scoping review (see Figure 2), it is evident that most of these risk factors concentrated on 3 out of the 4 categories. The least studied category (the knowledge gap) is

the category of driver-related factors. Indeed, the potential risk factors under this category (such as individual driver's traits and personalities) can be just as important as other categories of risk factors. For example, people with Type-A personality have been shown to be linked to rage and aggression. Type-A personality is a personality type with attributes such as high levels of competitiveness and impulsiveness.[39-40] Specifically, in the context of driving, Type-A personality has been shown to be associated with increased risk of accidents, traffic rules violation, impulsive and reckless driving habits and road rage.

One limitation inherent to the methodology of scoping review is that, although we have broadly mapped out the different types of collisions and risk factors, we did not systematically appraise our findings. In this regard, a systematic review is called for. A systematic review is also useful to minimize various research and publication biases as well as to control between-studies and within-studies variability. Secondly, the lack of a standard reporting guideline hampered our endeavor to conclusively identify the most common types of collisions involving ambulances. Lastly, as most of the articles in our review originated from developed countries (in particular, the USA and United Kingdom), the findings reported here might differ should a similar study is conducted in the setting of a developing country. This is because the road conditions, the drivers' behaviors and attitudes, the traffic congestion as well as the ambulance maintenance may be substantially different in a developing country as compared to that in a developed country. Hence, there is a need for more studies on ambulance accidents to be conducted in the setting of a developing country.

CONCLUSIONS

In this scoping review, we have identified 9 major risk factors described in the literature on ambulance accidents. The two most common risk factors studied are (1) the use of L&S and (2) driving at intersection. Most of these risk factors can be mapped into three categories of risk factors: task-related factors, vehicle-related factors and environment-related factors. The category of risk factors least studied is the category of driver-related factors. The lack of standard reporting guideline hampered our quest to identify the main types of ambulance accidents reported in literature. As such, it is hoped that this scoping review may serve as a springboard for more elaborative in-depth systematic reviews of selective risk factors of ambulance accidents or future research in ambulance accidents.

DECLARATIONS

Competing interests:
The authors declare that they have no competing interests

Funding:
None

Authors' contributions:
Both authors were involved in the initial conception of the study design. KSC conducted the initial search for the articles in MEDLINE and CINAHL. Both authors independently screened the eligibility of articles for inclusion. Both authors were involved in the quantitative and qualitative synthesis of the articles. KSC drafted the manuscript and both authors approved the final draft of the manuscript.

ACKNOWLEDGEMENT

The authors would like to acknowledge Universiti Malaysia Sarawak for the support rendered for this publication.

REFERENCES

1. Saunders CE, Heye CJ. Ambulance Collisions in an Urban Environment. Prehosp Disaster Med 1994; 9(2): 118-24.
2. Kahn CA, Pirrallo RG, Kuhn EM. Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective analysis. Prehosp Emerg Care 2001; 5(3): 261-9.
3. Custalow CB, Gravitz CS. Emergency medical vehicle collisions and potential for preventive intervention. Prehosp Emerg Care 2004; 8(2): 175-84.
4. Sanddal TL, Sanddal ND, Ward N, Stanley L. Ambulance Crash Characteristics in the US Defined by the Popular Press: A Retrospective Analysis. Emerg Med Int 2010: 525979.
5. Watanabe BL, Patterson GS, Kempema JM, Magallanes O, Brown LH. Is Use of Warning Lights and Sirens Associated with Increased Risk of Ambulance Crashes? A Contemporary Analysis Using National EMS Information System (NEMSIS) Data. Ann Emerg Med 2019; 74(1): 101-9.
6. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. International Journal of Social Research Methodology 2005; 8(1): 19-32.
7. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Medical Research Methodology 2018; 18(1): 143.
8. Aromataris E, Riitano D. Constructing a search strategy and searching for evidence. A guide to the literature search for a systematic review. Am J Nurs 2014; 114(5): 49-56.
9. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med 2018; 169(7): 467-73.
10. Weiss SJ, Ellis R, Ernst AA, Land RF, Garza A. A comparison of rural and urban ambulance crashes. The American Journal of Emergency Medicine. 2001; 19(1): 52-6.
11. Becker LR, Zaloshnja E, Levick N, Li G, Miller TR. Relative risk of injury and death in ambulances and other emergency vehicles. Accid Anal Prev. 2003;35(6):941-8.
12. Ray AF, Kupas DF. Comparison of crashes involving ambulances with those of similar-sized vehicles. Prehosp Emerg Care. 2005; 9(4): 412-5.
13. Ray AM, Kupas DF. Comparison of Rural and Urban Ambulance Crashes in Pennsylvania. Prehosp Emerg Care. 2007; 11(4): 416-20.
14. Lutman D, Montgomery M, Ramnarayan P, Petros A. Ambulance and aeromedical accident rates during emergency retrieval in Great Britain. Emerg Med J. 2008; 25(5): 301-2.
15. Sanddal ND, Albert S, Hansen JD, Kupas DF. Contributing factors and issues associated with rural ambulance crashes: literature review and annotated bibliography. Prehosp Emerg Care. 2008; 12(2): 257-67.
16. Studnek JR, Fernandez AR. Characteristics of Emergency Medical Technicians Involved in Ambulance Crashes. Prehosp Disaster Med. 2008; 23(5): 432-7.
17. Auerbach PS, Morris JA, Jr., Phillips JB, Jr., Redlinger SR, Vaughn WK. An analysis of ambulance accidents in Tennessee. JAMA. 1987; 258(11): 1487-90.

18. Pirrallo RG, Swor RA. Characteristics of fatal ambulance crashes during emergency and non-emergency operation. Prehosp Disaster Med. 1994; 9(2): 125-32.
19. Biggers WA, Jr., Zachariah BS, Pepe PE. Emergency medical vehicle collisions in an urban system. Prehosp Disaster Med. 1996; 11(3): 195-201.
20. Ersoy G, Ersoy O, Yuksekbas O, Kurnaz G, Akyildiz EU, Ekemen S. Why did the patient die? The relationship between ambulance accidents and death of patients: forensic medical issues. J Forensic Leg Med. 2012; 19(8): 474-9.
21. Eksi A, Celikli S, Catak I. Effects of the institutional structure and legislative framework on ambulance accidents in developing emergency medical services systems. Turk J Emerg Med. 2015; 15(3): 126-30.
22. Chiu P-W, Lin C-H, Wu C-L, Fang P-H, Lu C-H, Hsu H-C, et al. Ambulance traffic accidents in Taiwan. Journal of the Formosan Medical Association. 2018; 117(4): 283-91.
23. Missikpode C, Peek-Asa C, Young T, Hamann C. Does crash risk increase when emergency vehicles are driving with lights and sirens? Accid Anal Prev. 2018;113:257-62.
24. De Lorenzo RA, Eilers MA. Lights and siren: a review of emergency vehicle warning systems. Annals of emergency medicine. 1991; 20(12): 1331-5.
25. Hsiao H, Chang J, Simeonov P. Preventing Emergency Vehicle Crashes: Status and Challenges of Human Factors Issues. Human Factors. 2018; 60(7): 1048-72.
26. Clawson JJ, Martin RL, Cady GA, Maio RF. The wake-effect--emergency vehicle-related collisions. Prehosp Disaster Med. 1997;12(4):274-7.
27. Kupas DF, Dula DJ, Pino BJ. Patient outcome using medical protocol to limit "lights and siren" transport. Prehosp Disaster Med. 1994; 9(4): 226-9.
28. Brown LH, Whitney CL, Hunt RC, Addario M, Hogue T. Do warning lights and sirens reduce ambulance response times? Prehosp Emerg Care 2000; 4(1): 70-4.
29. Marques-Baptista A, Ohman-Strickland P, Baldino KT, Prasto M, Merlin MA. Utilization of warning lights and siren based on hospital time-critical interventions. Prehosp Disaster Med. 2010; 25(4): 335-9.
30. Hunt RC, Brown LH, Cabinum ES, Whitley TW, Prasad NH, Owens CF, Jr., et al. Is ambulance transport time with lights and siren faster than that without? Ann Emerg Med 1995;25(4):507-11.
31. O'Brien DJ, Price TG, Adams P. The effectiveness of lights and siren use during ambulance transport by paramedics. Prehosp Emerg Care. 1999; 3(2): 127-30.
32. Murray B, Kue R. The Use of Emergency Lights and Sirens by Ambulances and Their Effect on Patient Outcomes and Public Safety: A Comprehensive Review of the Literature. Prehosp Disaster Med. 2017; 32(2): 209-16.
33. Kerstholt JH. The effect of time pressure on decision-making behaviour in a dynamic task environment. Acta psychologica. 1994; 86(1): 89-104.
34. Dozza M. What factors influence drivers' response time for evasive maneuvers in real traffic? Accident Analysis & Prevention. 2013; 58: 299-308.
35. Witzel K, Hoppe H, Raschka C. The influence of the mode of emergency ambulance transportation on the emergency patient's outcome. Eur J Emerg Med. 1999; 6(2): 115-8.
36. Gazis D, Herman R, Maradudin A. The Problem of the Amber Signal Light in Traffic Flow. Operations Research. 1960; 8(1): 112-32.
37. Polders E, Daniels S, Hermans E, Brijs T, Wets G. Crash Patterns at Signalized Intersections. Transportation Research Record. 2015; 2514(1): 105-16.
38. Spek ACE, Wieringa PA, Janssen WH. Intersection approach speed and accident probability. Transportation Research Part F: Traffic Psychology and Behaviour. 2006; 9(2): 155-71.
39. Baron RA, Neuman JH, Geddes D. Social and personal determinants of workplace aggression: Evidence for the impact of perceived injustice and the Type A Behavior Pattern. Aggressive Behavior. 1999; 25(4): 281-96.
40. Faunce GJ, Mapledoram PK, Soames Job RF. Type A behaviour pattern and attentional bias in relation to anger/hostility, achievement, and failure. Personality and Individual Differences. 2004; 36(8): 1975-88.