The Evidence Base for a New "Vehicle in Water" Emergency Dispatch Protocol

Gordon G. Giesbrecht, PhD

Faculty of Kinesiology and Recreation Management, University of Manitoba, Winnipeg, Manitoba, Canada

Corresponding Author:
Gordon Giesbrecht, PhD
108 Frank Kennedy Centre
University of Manitoba
Winnipeg, Canada R3T 2N2
+1 (204) 474-8646
Gordon.giesbrecht@umanitoba.ca

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INTRODUCTION

Every year, 350-400 people die in submersed vehicles in North America, with these deaths accounting for up to 10% of all drownings.[1-4] Vehicle submersion has the highest fatality rate of any type of single vehicle accident.[5] Most of these incidents are survivable, as vehicles usually hit the water in an upright position causing, at most, non-disabling injuries; in these cases death results from either ineffective, or no, self-rescue actions by the victim(s).

In general, emergency dispatch protocols for sinking vehicles have been either nonexistent or ineffective to deal with this rapidly deteriorating situation in which a vehicle will fill with water and sink completely (if the water is deep enough). In 2001, the emergency dispatch recording from a high profile vehicle drowning in Florida revealed the limitations of a protocol that simply concentrated on determining the incident location and urging the victim to remain calm while awaiting rescue; the victim drowned prior to arrival of emergency responders.[6] This incident ignited calls for changes to the emergency dispatch protocols to refocus attention on advising the vehicle occupants on how to exit the vehicle themselves before emergency responders arrive. Even though emergency dispatch recordings continued to reveal the same approach over the next ten years, there was no progress in changing the protocols.

In 2010, the International Academies of Emergency Dispatch® (IAED™) commissioned a "Vehicle Submersion Subcommittee" to create an evidence-based revision of the existing "vehicle in water" protocol. A new protocol was created for the Fire Priority Dispatch System™ (FPDS®) based on a combination of published research (primarily from the Netherlands,[7-11] Operation Submersed Transportation Automobile Research (STAR),[12] University of Oklahoma,[13,14] and Operation Automobile submersion: Lessons in Vehicle Escape (ALIVE),[4,15-18]), survey results, and when necessary, reasoned, logical advice from experts. The subcommittee's work resulted in the protocol being approved by the IAED Fire Council of Standards in 2013. Since its approval, the new protocol has been rolled out in the revised FPDS (version 6.0), released in late 2013, and also has been included in the latest versions of both the Police and Medical Priority Dispatch Systems™ (PPDS® v5.0, 2015; MPDS® v13.0, 2015, Priority Dispatch Corp, Salt Lake City, Utah, USA).

The new protocol follows newly created, and commonly accepted, public advice regarding a vehicle in water, which includes: don't panic, do not use your cell phone (until safely out of the vehicle), and follow four actions points (SEATBELTS off; WINDOWS open or broken; CHILDREN released from restraints; and OUT immediately).[4] Since sinking vehicle occupants may still call 9-1-1 for assistance, the new protocol follows the principles of this advice in order to promote rapid self-exit and survival.

The following section lists the issues that required supporting evidence during the preparation of this new protocol. The final section describes the protocol in detail and lists the level of recommendation for each step. Recommendations are graded based on the quality of supporting evidence and the balance between benefits and risks, similar to criteria published by the American College of Chest Physicians (Table 2).[19] In this system, recommendations are rated 1 A, B, or C, or 2 A, B, or C, with 1 and 2 indicating strong and weak recommendations respectively, and A, B, and C indicating strong, moderate and low-quality supporting evidence.

Vehicle sinking characteristics

Several characteristics of sinking vehicle situations are well documented. First, because of the relatively low position of the engine, a vehicle in water is inherently stable in the upright position whether it lands in the water upright or upside down. Second, a vehicle will tilt in an engine-down attitude as it sinks. Finally, doors are very difficult, or impossible, to open in water because of increased pressure caused by a higher water level on the outside of the vehicle.[7,14,15,20]

However, one important characteristic that merits clarification is "sinking time." Traditionally "sinking time" has been described as the time from landing in the water until the disappears under the water surface; this has been described by Operation STAR and varies from a few to up to 8 minutes.20 However, recent work from Operation ALIVE has described two distinct phases during this "sinking time."[15] The first phase (Flotation Phase) lasts about one to two minutes and includes the time until the water level raises high enough to push against the side window(s); survival during this phase simply involves opening the window and exiting. The second phase (Sinking Phase) includes the rest of the time the vehicle is visible above the water surface. During this period, exit is hindered because pressure from the water prevents opening both doors and windows. Therefore the optimum period for self-rescue is the Flotation Phase, within the first minute of immersion.

Emergency response times

One of the assumptions involved in recent advice that "sinking vehicle occupants not use their cell phones to call emergency services" is the unlikelihood that rescue personnel will arrive soon enough to enact a rescue. Reported EMS times from notification until arrival at serious (i.e., ALS or fatal) vehicle crashes in urban areas have ranged between 4.8 minutes (Syracuse, NY) and 6.5 minutes (US average) over the past 15 years.[21,22] These response times increase in rural areas, ranging from 7.2 minutes (Miami Dade County, FL) to 12.1 minutes (Becker County, MN).[22,23] In Denver, 79% of response times are reported to be greater than 4 minutes, while in Calgary, less than 1% of response times are under 2 minutes; in the U.S., 48% of response times nationally are greater than 8 minutes.[24-26] This great disparity between response times and the one minute of opportunity for self-exit not only supports advice not to call emergency services but instead enact the self-rescue process, but also emphasizes that emergency dispatchers who do receive such calls must rapidly lead the caller through the self-rescue process rather than encouraging them to relax and wait for rescue.

Electric window function in water

Operation STAR demonstrated that vehicle batteries and electric motors can work for many minutes in submersed vehicles, providing video evidence of operating headlights and windshield wipers on vehicles sitting on the bottom of a lake.[20] Although there was no one inside the vehicles to operate the electric windows, they presumably would also have worked. However, it is also true that recent developments in vehicle design have resulted in electronic control of electric windows being integrated by an Intelligent Module (IM), and one recent study has demonstrated that when an IM becomes water-saturated, it fails to conduct controlling information to the electric window motors, rendering the window motors inoperative.[27] Since the IM units are generally located on the inside of the passenger compartment at about the level of the glove compartment, though, there is a period before the IM is immersed and saturated in which the IM (and thus the electric windows) will be functional—although the time would depend on factors such as rate of water influx and water resistance of the IM housing. Thus it is reasonable to expect that electric windows will work for a limited time (probably 15-60 seconds) after impact with water; this period is easily long enough to enact the self-rescue sequence. However, because this period is limited, variable, and unknown, it is advisable to open the windows before helping others with their restraints; delays in releasing children, or others who require assistance, could result in inoperable windows and being fatally trapped in the vehicle.

Breaking of windows

An open window is the exit of choice in a sinking vehicle (with the exceptions of sun roofs and the roof escape hatches in commercial vehicles). If a window cannot be opened, it must be broken. The general understanding of the public that a window can be broken with a 'hard or sharp object' is both misleading and vague. The best implement for breaking a window is a commercial device designed for this purpose, such as a rescue hammer or spring loaded center punch.[4] Most items found in a passenger vehicle are inadequate to break a window (it cannot be done with a cell phone, a high heel of a shoe, etc.), and if an implement is present (e.g., a carpenter's hammer) it is often hidden in a glove compartment or console or under a seat; this minimizes the probability that an occupant will remember that it is available during a stressful incident. It is therefore important that an emergency dispatcher be specific in questioning a caller and asking if they have something heavy and hard (like a hammer), or a center punch. They can also suggest that the caller look in the areas listed above.

It is very difficult to break a vehicle window by kicking it. If this is the only option, an occupant should be instructed to kick a side window because front and rear windshields are difficult to kick forcefully (due to factors including the head down position required to kick a rear window, and the sharp angles between the windows and the dash or rear shelf). Also, since the front, and many back, windows are laminated, even if they are broken, they will not shatter, necessitating breaking the seal and removing the entire window. To break a side window, force from both heals must be applied to the most stable portion of the glass, so more of the force is taken up by the window, rather than being absorbed by the vibrating door. Force applied to the center of the window or the side closest to the door handle may actually bend the door without breaking the window (Operation ALIVE, unpublished results). When force is applied to the side of the window closest to the door hinges (generally toward the front of the vehicle), the window is more stable and the force is more likely to break the window.

It is also important to note that a window is broken more easily when the force across the window is equal. This occurs either before the water reaches the windows (e.g., during the optimal Flotation Phase) or when the vehicle is completely full of water (later in the Submersion Phase), a period when self-rescue is very improbable. During the Sinking Phase when water is exerting more force on the outside of the window, it is difficult or impossible to break the window (Operation ALIVE, unpublished results). Thus, the instructions to open the window, and then if necessary to break the window, must be given as early as possible during the call (but only after the seatbelt has been removed).

Child restraints, children and others requiring assistance

Children, or other individuals requiring assistance with removing restraints and/or exiting, must be considered. Anyone requiring assistance should have their restraints unfastened and be helped/pushed out an open window first, as it is very difficult to reach back in to pull someone out, especially if the water is flowing in the window and the vehicle is sinking rapidly (Operation ALIVE, unpublished results).

It has been suggested that children can be removed while still in their car seats, as the seats may be buoyant. This is contraindicated because, even though some models of car seat are buoyant, because of their size it will be difficult, if not impossible, to remove most car seats through most car windows. Therefore, children should have their restraints unfastened and either be directed to exit through the window and wait while holding on to the vehicle, or be manually pushed out the window ahead of the able bodied adult. One final consideration regarding car seat design is releasing the restraint connectors. While the waist connectors are standardized (a red button must be pushed to release the metal inserts from the buckle), there is no such standardization for the plastic connector attaching the shoulder straps at chest level. The releases for these connectors have many different designs and can often be difficult to unfasten, especially when one is rushed or panicking. Therefore, an emergency dispatcher may need to direct the caller to calm down and methodically release these connectors.

The final issues involve multiple children: "is there a preferred order of assistance?" and, "should an order be suggested to the caller?" It was agreed that the new protocol should indeed prescribe an order. It is likely that the more complicated, and the less familiar, an emergency action is (such as removing multiple children from a sinking vehicle), the more time a victim will take to make a decision; there will also be an increased probability of an incorrect decision (if any decision is made).[28] Thus, just as the instructions for persons who are on fire to "stop, drop and roll" are both explicit and given in the correct order, it was agreed that an order should be given for multiple children, and that children should be released and helped from the oldest to the youngest.

This order is not based on differential value of the children, but on what would be likely to produce the highest survival rate. Older children can be given instructions to exit the vehicle and hold on, or helped out quickly, before focusing on the next child. Thus, children needing more help and more time are sequentially helped. If the order is reversed, it is more possible that the more difficult extraction (that from a rear-facing child seat compared to a front-facing booster seat, for example) might keep anyone from escaping. One additional problem with starting with the youngest is if the youngest child (i.e., an infant) is removed from a car seat first, the adult will have difficulty helping the other children while holding on to the infant, who will not be able to function without assistance.

Physics of door/window opening in water

As described above, doors and windows are difficult, or impossible, to open when there is a higher water pressure from the outside. It is generally understood that when the vehicle is full of water, the pressure will be equal and a door can then theoretically be opened (assuming nothing else is physically preventing this action). This has led to the belief that an occupant can place their head near the rear windshield (where the last air will be in a front-engine vehicle that has tilted nose downward), and take a last breath

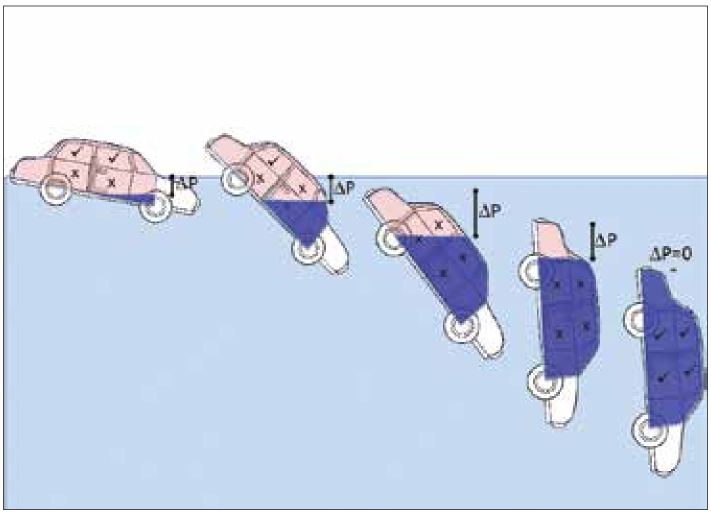

Figure 1. Pressure gradient (ΔP) as vehicle sinks. Air capsule includes passenger cabin and trunk. ΔP = water level outside–inside. When cabin is full, pressure gradient still exists. ΔP = 0 when all the air has escaped from the trunk.

before opening the door(s). What is less understood is that the air compartment of a vehicle includes not only the passenger compartment but also the trunk area; thus, the back seat does not create a separate air compartment, but merely prevents movement into the trunk area (see Figure 1). Therefore, even after a last breath is taken, and the passenger compartment no longer has air in it, there is still a pressure gradient against the doors until the remaining air escapes through the trunk. Although this emphasizes the importance of escaping during the Flotation Phase, it does not preclude the emergency dispatcher from preparing the occupant to hold their breath and try to open the door once they run out of air in the passenger compartment.

Summary of new protocol

Figure 2 shows the algorithm upon which the new vehicle submersion protocol is based. In general, once it is determined that the caller is in a sinking vehicle, focus is changed to instructing the caller to self-rescue [Recommendation level 1A]. After releasing their own seatbelt(s), occupants are instructed to open rear side windows (as these will be above water longer than the front windows) [Recommendation level 1A]. Front side windows are a second choice if rear windows cannot be opened (e.g., they may be child-proofed, or mechanically damaged) [Recommendation level 1A]. Once an exit is established, occupants are asked if there are any children or others who require assistance with restraints or exit. If so, occupants are directed to release the oldest (or more able) children/persons first [Recommendation level 1C] and push them out through the window [Recommendation level 1B]. Occupants are then instructed to exit as quickly as possible [Recommendation level 1A]. The caller is then advised that s/he may hold on to the floating vehicle to rest and plan the best route before swimming to the nearest shore if necessary [Recommendation level 1B].

If no windows can be opened, instructions are given to break a window. The caller is instructed to move into the back seat [Recommendation level 1A]. Specific implements and areas in which to look are suggested to increase the chance of the caller finding an appropriate tool/object if one is in the vehicle [Recommendation level 1B]. The caller is then advised where to hit or kick the side window (near frame nearest front of vehicle) if necessary [Recommendation level 1B].

If no exit can be established, the dispatcher prepares the caller for the eventuality that the phone may stop working. The caller is advised that the water will continue to rise to a point where the caller must take a final breath. Instructions are then given to hold the breath and try to open the doors, and to continue to do so as long as possible [Recommendation level 1B]. Although success is very unlikely at this point, it is important to keep trying because eventually all the air will escape from the trunk and the pressure will be equal, and at that point the door may be opened if it is unlocked. Thus the dispatcher is providing self-rescue actions from the first Flotation Phase (when success if most likely) until the end of the Submersion Phase. Even though success is unlikely at this latter point, giving specific action instructions is better than merely encouraging the victim to be calm and wait for rescue.

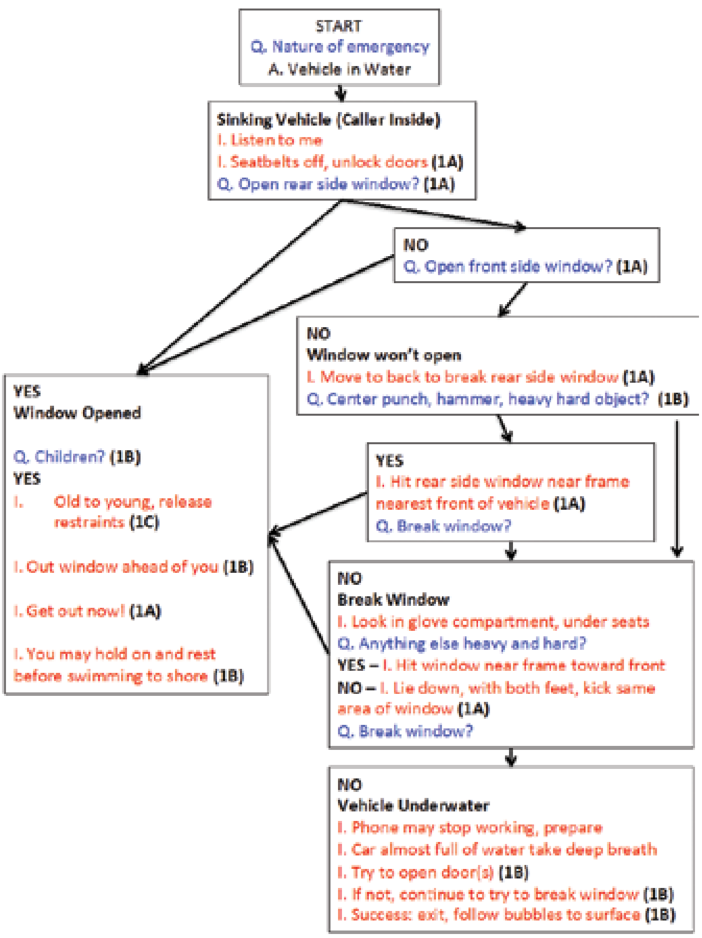

Figure 2. New vehicle submersion algorithm. Abbreviations: Q, Question from dispatcher; I. Instructions to caller; A, Answer from caller. Level of recommendation indicated in parentheses (1 = strong recommendation, and A, B and C indicating strong, moderate and low quality supporting evidence respectively).

CONCLUSION

The new "vehicle in water" protocol should prevent drowning deaths in occupants who call emergency dispatch from a sinking vehicle. In this scenario, the highest probability of survival is for the occupant(s) to exit the vehicle themselves, as it is very unlikely that a dispatched rescue team will arrive in time to achieve a successful rescue. As more emergency dispatch units enact the new protocol, future research can determine if survival rates increase for callers to these emergency services. Meanwhile efforts should continue to educate the public that they should not use their cell phones but rather enact the four-step self-exit process: SEATBELTS off; WINDOWS open or broken; CHILDREN released from constraints; OUT immediately.

Most, but not all, instructions in the new protocol are based on scientific evidence, while remaining aspects are based on experiential observations, expert opinion, and/or logical decisions. Although future research could address these areas to potentially improve the quality of this new protocol, the new protocol should be a significant improvement over older practices of concentrating on incident location and advising occupants to be calm instead of taking constructive self-rescue survival actions.

REFERENCES

1. Austin R. Drowning deaths in motor vehicle traffic accidents. 2011:1-8 accessed from www-nrd.nhtsa.dot.gov/departments/esv/22nd/, July 18, 2011. www-nrd.nhtsa.dot.gov/departments/esv/22nd/. Accessed December 11, 2015.
2. Road Safety and Motor Vehicle Regulation Directorate. Trends in motor vehicle traffic collision statistics 1988-1997. Ottawa, ON: Transport Canada; February 2001 Feb. Report No: TP 13743 E.
3. Wintemute GJ, Kraus JF, Teret SP, Wright MA. Death Resulting from Motor Vehicle Immersions: the Nature of the Injuries, Personal and Enviromental Contributing Factors, and Potential Interventions. *AJPH*. September 1990; 80(9):1068-1074.
4. McDonald GK, Giesbrecht GG. Vehicle submersion: a review of the problem, assocaited risks, and survival information. *Aviat Space Environ Med*. 2013;84(5):498-510.
5. Baker S, O'Neill B, Marvin M, Li G. The injury fact book: vehicle immersion. Second ed (pp. 1242-1243). New York: Oxford University Press, 1992.
6. National Broadcasting Company. N.B.C. Dateline: Life on the Line [videorecording] [News cast]. 1996, 2001.
7. SWOV. Submerging vehicles. Voorburg, NL: Institute for Road Safety Research (SWOV); 1973 1973. Report No: 1973-1E. Report 1973-E1.
8. Vis AA. Auto's te water. Leidschendam, NL: Institute of Road Safety Research (SWOV);1989. Report No: R-89-16. R-89-16.
9. Vis AA. Auto's te water! Leidschendam: Institute of Road Safety Research (SWOV);1992. Report No:R-89-16.
10. vanKampen LTB. Problemen met ontsnapping en bevrjding uit auto's te water? [Problems with escape, and liberation from cars to water?]. Leidschendam, NL: Institute of Road Safety Research (SWOV);2002. Report No: R-2002-28 I.
11. vanKampen LTB. Omvang, aard en ernst van ongevallen met auto's te water [Size, nature and severity of accidents with cars in the water]. Leidschendam,NL: Institute of Road Safety Research (SWOV); 2002. Report No: R-2002-28 II. R-2002-28 II.
12. Submerged Transportation Accident Research Operation STAR II [videorecording]. East Landsing, MI; Michigan State Police:1997.
13. Sliepcevich CM, Steem WD, Purswell JL, Ice JN, Welker JR. Escape worthiness of vehicles and occupant survival. Norman, OK: U.S. Department of Transportation; December 1970. Report No: 1729-FR-1-1.
14. Sliepcevich CM, Steen WD, Purswell JL, Krenek RF, Welker JR, Peace TD, Cullen RE, Ice JN, Reni RG Jr. Escape worthiness of vehicles for occupancy survivals and crashes. First Part: Research Programs. Norman, OK: U.S. Department of Transportation; 1972 Jul. Report No: 1770-FR-1-1.
15. Giesbrecht GG, McDonald GK. My car is sinking: Operation ALIVE (Automobile submersion: Lessons in Vehicle Escape). *Aviat Space Environ Med*. Aug 2010; 81(8):779-784.
16. Giesbrecht GG, McDonald GK. Exit strategies and safety concerns for machinery occupants following ice failure and submersion. *Aviat Space Environ Med*. 2011; 82(1):52-57.
17. Gagnon D, McDonald GK, Pretorius T, Giesbrecht GG. Clothing bouyancy affects underwater horizontal swim distance after exit from a submersed vehicle simulator. *Aviat Space Enviro Med*. 2012; 83(11):1077-1083.
18. McDonald GK, Giesbrecht GG. Escape from a submersible vehicle simulator wearing different thermoprotective flotation clothing. *Aviat Space Environ Med*. 2013; 84(7):708-715.
19. Guyatt G, Gutterman D, Baumann MH, Addrizzo-Harris D, Hylek EM, Phillips B, Roskob G, Zelman-Lewis S, Schunemann H. Grading strength of recommendations and quality of evidence in clinical guidelines: report from an American College of Chest Physicians task force. *Chest*. 2006;129:174-181.
20. Donohue W. Operation Submerged Transportation Accident Research (S.T.A.R). Michigan Department of State Police; 1991 Report No: Final Report.
21. Brown LH, Whitney CL, Hunt RC, Addario M, Hogue T. Do warning lights and sirens reduce ambulance response times? *Prehospital Emerg Care*. 2000; 4(1):70-74.
22. Lambert TE, Meyer PB. Ex-urban sprawl as a factor in traffic fatalities and EMS response times in the southeastern United States. *J Economic Issues*. 2006; XL(4):941-953.
23. Ho J, Lindquist M. Time saved with the use of emergency warming lights and siren while responding to requests for emergency medical aid in a rural enviornment. *Prehospital Emerg Car*e. 2001; 5(2):159-162.
24. Pons PT, Haukoos JS, Bludworth W, Cribley T, Pons KA, Markovchick VJ. Paramedic response time: does it affect patient survival? *Academic Emerg Med*. 2005; 12(7):594-600.
25. Blanchard IE, Doig CJ, Hagel BE, Anton AR, Zygun DA, Kortbeek JB, Powell DG, Williamson TS, Fick GH, Innes GD. Emergency medical services resonse time and mortality in an urban setting. *Prehospital Emerg Care*. 2011; 16(1):142-151.
26. Trowbridge MJ, Gurka MJ, O'Connor RE. Urban sprawl and delayed ambulance arrival in the U.S. *Am J Preventive Med*. 2009; 37(5):428-432.
27. Buning L R, Kessels J F, Merts M, Pauwelussen J P, Visser A G. Window operating mechanisms and door locking systems. 1 July Deleft: The Ministry of Transport, Public Works and Water Management Rijkswaterstaat Centre for Transport and Navigation; 2008 Jul:Report No: Definitive 1.0.
28. Giesbrecht G. Bad decisions, poor outcomes: a visual model for how humans make some threatening events worse. *Journal of Special Operations Medicine*. 2005;5(1):24-27.