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1 **Prehospital Response Time and Traumatic Injury—A Review**

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1 ABSTRACT

2 A significant proportion of fatalities from motor vehicle collisions (MVC) could be prevented
3 through better emergency medical service (EMS) care. Despite a lack of conclusive research,
4 there is a consensus that prehospital time (the time between the MVC and the patient's arrival at
5 the hospital) must be reduced as much as possible. Many studies use response time (the time
6 between EMS dispatch and arrival at the scene) as an indicator of overall prehospital time and a
7 metric of EMS performance. However, there are other components of prehospital time that may
8 be equally important, including the discovery time between the collision and EMS notification,
9 the on-scene time, and the transport time from the scene to the hospital. In rural MVCs, the
10 discovery time can be substantial if there are no witnesses or survivors capable of calling
11 emergency services. Technologies that automatically detect MVCs can shorten discovery times
12 in such circumstances. Transport times depend on the distance between the crash scene and the
13 hospital; this time could be reduced by increasing access to trauma centers, especially in rural
14 areas. On scene time is a component of the total time, however there is a trade-off between
15 minimizing scene time to reduce total time and providing optimal on-scene care. Increasing
16 capacity of EMS personnel and/or utilizing technology such as telemedicine should be
17 considered as part of this trade-off. Future research is needed to determine the relative benefits
18 and costs of reducing any of these segments of prehospital time.

19

20 *Keywords:* EMS, Response Time, Crash, Prehospital, Keyword, Keyword

21

1 INTRODUCTION

2 In 2016, there were 34,439 fatal motor vehicle collisions in the United States (1). It is possible
3 that a significant proportion of these fatalities could have been prevented with faster response
4 times and better emergency medical care. For this reason, the Towards Zero Deaths Steering
5 Committee, comprised of representatives from various highway safety stakeholders, identified
6 enhanced emergency medical services as a key area in its national safety strategy (2).

7 This paper explores the factors affecting prehospital time, recommends strategies for
8 reducing this time and improving prehospital care, and summarizes areas in which further
9 research is needed.

10

11 Importance of Prehospital Time

12 There is widespread belief in the significance of the ‘golden hour’ immediately following an
13 injury, during which time resuscitation, stabilization and transport to a medical facility offer the
14 greatest chance of survival for the patient (3). By reducing prehospital time, more advanced
15 medical care can be provided sooner, with the goal of reduced mortality. However, there is a lack
16 of conclusive research on whether the golden hour is important for all types of injuries.

17 In some cases in which patients need to be treated prior to transfer to a hospital or trauma
18 center, reduced prehospital time may have a negative impact on patients’ health outcomes,
19 especially if necessary treatment is deferred for the sake of getting the patient to the hospital as
20 quickly as possible. Additionally, it is likely that reducing prehospital time below a certain
21 threshold will lead to diminishing returns for patient survival. For example, patient outcomes
22 may be similar for prehospital times below 15 minutes, meaning that a reduction in prehospital
23 time from 15 minutes to 10 minutes may not change patient outcomes enough to justify the cost
24 of the reduction.

25 Many studies use response time, the time between EMS dispatch and arrival at the scene,
26 as an indicator of overall prehospital time and a metric of EMS performance. However, the
27 literature disagrees about whether response time is an important factor in patient survival. For
28 example, one study found that response times only improved survival chances when they were
29 less than five minutes (4). A study of severely injured trauma patients in Korea found that longer
30 prehospital times had no impact on mortality and that mortality decreased when scene times were
31 longer than six minutes (5). However, another study found that increased EMS prehospital time
32 was likely to be associated with higher mortality rates in rural areas in which the mean EMS
33 response time was greater than 14 minutes (6). A study of motor vehicle collisions in Spain
34 found that when response times were reduced from 25 minutes to 15, the probability of fatality
35 decreased by one third (7). In yet another study, the author cautioned that some options for
36 decreasing ambulance service times not only have prohibitive costs, but increase the risk of
37 safety to patients, emergency medical service personnel, and the public because ambulances have
38 a high collision rate. The author further stated that patient outcome should be the main standard
39 of EMS performance (8).

40 In addition, response time may not be important for all types of patients. Reductions in
41 prehospital time may have a greater impact on less severely injured patients since extremely
42 severely injured patients are likely to die regardless of how soon they are treated (6). Response
43 time may also have different impacts depending on the type of emergency—most studies on the
44 impact of response time have been focused on cardiac arrest patients (9).

45

1 According to one study, previous research failed to account for the endogeneity (i.e.,
2 EMS personnel are usually aware of how serious an injury is and may adjust the speed of their
3 response accordingly when determining the impact on patient outcomes) which may have
4 resulted in biased estimates of the effect of response times downward toward finding no effect.
5 When Wilde accounted for this endogeneity by using an instrument variable, which affects the
6 explanatory variable but has no independent effect on the dependent variable, the author found
7 that a one-minute increase in response time led to an 8 to 17 percent increase in mortality (9).

8 There are other components of prehospital time that may be of equal, or greater,
9 importance than response time. One study defined total prehospital time as the time between the
10 emergency call and arrival of the patient at the hospital (3). The author further breaks this time
11 down into activation time (the time between the call and EMS deployment), response time (the
12 time between the call and EMS arrival at the crash scene), on-scene time (the time spent on scene
13 by EMS), and transport time (the time between leaving the crash scene and arriving at the
14 hospital). Other important segments of prehospital time include the discovery time between the
15 crash and the 911 call, and the time between arriving at the scene and arriving at the hospital,
16 which can be substantial if vehicle extraction is necessary.

17 **FACTORS AFFECTING PREHOSPITAL TIME**

18 **Incident Detection and Dispatch**

19 Traditionally, EMS agencies are notified of a motor vehicle collision when a witness or someone
20 involved in the collision makes a 911 call. If there are no witnesses and no one involved in the
21 crash is capable of making an emergency call, the discovery time between the accident and EMS
22 notification can be dangerously long. One study found that in the state of Texas this incident
23 detection time is three times as long for rural motor vehicle collisions as it is for urban ones,
24 probably due to the geographic isolation of rural areas (10).

25 There are also in-vehicle systems, known as Advanced Automatic Collision Notification
26 (AACN) technologies, that can detect a crash occurrence and send its location to independent
27 emergency call centers. Personnel at these centers then attempt to make voice contact with
28 vehicle occupants, and if they determine it is not a false alarm, they make a 911 call on the
29 occupants' behalf. These systems can also estimate the likelihood of severe injury in a crash—
30 however the algorithms used for these estimates are not consistent across various technologies
31 (2).

32 Even when a 911 call is made directly after a crash occurs, there may still be a significant
33 period of time before an EMS vehicle can be dispatched. Traditional 911 systems can identify a
34 caller's location automatically only when the call comes from a landline (2). Otherwise, the EMS
35 dispatcher must rely on information from the witness or victim, which may be unreliable or
36 unavailable. Enhanced 911 systems have the ability to accurately locate calls made from cell
37 phones and can identify the nearest emergency call center, however, this system has not yet been
38 fully implemented nationwide. Recently, next generation 911 (NG911) systems have been
39 developed. These systems can receive text messages, pictures, and videos from callers to provide
40 responders with more accurate information about the crash scene (2). As of 2017, a total of 6
41 states are completely covered and 13 states are partially covered by NG911 capable services
42 (11). Using NG911, AACN technologies could directly contact EMS agencies, bypassing the
43 need for independently operated emergency call centers. These systems reduce the time between
44 the 911 call and EMS dispatch.

1 **Differences in Rural and Urban Accessibility**

2 While only 19 percent of the United States population resides in rural areas, over half of all
3 traffic fatalities involve rural motor vehicle collisions. In 2011, a total of 75 percent of drivers
4 who were injured in motor vehicle collisions and died during transport to the hospital were in
5 rural areas (2).

6 Rural motor vehicle collisions are not intrinsically more deadly—one study found that
7 rural and urban motor vehicle crashes result in similar injury severities (6). Mortality rates are
8 similar for severely injured patients regardless of whether the incident occurs in a urban or a
9 rural setting; this indicates that patients with lower injury severity contribute to the generally
10 higher mortality rate in rural areas (6).

11 This discrepancy could be caused by the relative inaccessibility of trauma centers in rural
12 areas. Although patients who are treated at Level 1 trauma centers within one hour of injury are
13 25 percent less likely to die as a result, more than 45 million U.S. citizens live over an hour away
14 from a Level 1 or 2 trauma center (2). In a study of motor vehicle collisions in Texas, Lu and
15 Davidson found that activation time, response time, and transport time were significantly longer
16 for fatal motor vehicle collisions in rural areas than in urban areas (10).

17 18 **Land Use**

19 According to one study, urban sprawl is associated with longer EMS response time (12). The
20 authors found that counties with characteristics of sprawl including low density construction,
21 limited street connectivity, and distance between residential development and civic and
22 commercial districts showed greater probability of delayed ambulance arrival than counties with
23 smart growth features. The authors asserted that integrating more comprehensive land-use
24 metrics, including measures of urban sprawl, into EMS dispatch algorithms could improve use of
25 resources and potentially improve response reliability (12).

26 27 **FACTORS AFFECTING PREHOSPITAL CARE**

28 **Triage**

29 In the context of prehospital care, triage, the process of prioritizing actions in an emergency,
30 begins when a 911 call is received, at which point dispatchers must decide which EMS crew to
31 send to the scene. Triage continues when EMS responders decide whether the emergency
32 requires the use of sirens and lights as they travel to the scene. Once at the scene, the responders
33 must decide whether to stabilize the patient at the site or to rush the patient to the hospital.
34 Finally, the responders must decide which trauma center is most appropriate and whether use
35 sirens and lights is necessary for the trip.

36 Without proper triage, EMS agencies cannot effectively prioritize which resources to
37 provide to which patients. Unnecessary use of sirens and lights by EMS vehicles can result in
38 harm to ambulance crews and the public (8). EMS personnel may conclude that the use of such
39 warning signals allow them to disregard stop signs or traffic signals and to drive against traffic.
40 In addition, drivers are generally unclear on how to respond to visual and audible signals from
41 emergency vehicles. One of the most effective ways to reduce these secondary crashes is to
42 establish and enforce a complete stop rule at intersections and at traffic signals when requesting
43 the right-of-way (13). EMS responders have fatality rates as high as those for police and
44 firefighters, and 75 percent of these fatalities involve transportation (2). Ambulances are at least
45 seven times more likely to crash than heavy trucks, and two-thirds of fatalities caused by
46 ambulance collisions are among occupants of other vehicles or pedestrians (2). When EMS

1 vehicles use sirens and lights, these risks may be exacerbated. However, there is currently no
2 evidence-based model that determines when the risk of using sirens and lights is justified;
3 instead, individual EMS responders are responsible for this decision (2).

4 Furthermore, the EMS vehicle that is closest to the scene may lack the necessary
5 equipment to address a particular emergency. Although sending the closest vehicle may result in
6 the shortest response time, comprehensive telephone triage that identifies the tools needed for the
7 situation prior to deciding which vehicle to send could improve patient survival, even while
8 increasing prehospital times (8).

9 **Telemedicine**

10 Telemedicine is the provision of medical services via information and communication
11 technologies to remotely located healthcare workers and patients. It is intended to extend the
12 reach of medical specialty services and is of particular benefit in the case of prehospital care in
13 acute emergencies for which treatment delays may negatively impact outcome (14).

14 Amadi-Obi notes that telemedicine has been most extensively studied in the area of stroke
15 management. Telemedicine can provide remote access to a stroke specialist, which the author
16 asserts is a promising solution in locations lacking qualified local medical experts. This is known
17 as the “hub and spoke model,” wherein telemedicine links underserved areas (the spoke) with a
18 centrally located stroke expert (the hub). The author further notes that telemedicine provides
19 similar quality of care to that of in-person medicine, and contends that there is no statistical
20 difference in short-term and long-term mortality between telemedicine and face-to-face
21 consultation. While telemedicine is more expensive than traditional medicine, there is potential
22 for significant cost savings as a result of reduced length of hospital stays (14).

23 There is less research on the impact of telemedicine on trauma management. According to
24 Amadi-Obi, it is appropriate in addressing major incidents in which a significant deficit of
25 healthcare professionals can be resolved via teleconsultation. For example, teleradiology has
26 improved diagnoses and reduced the expense of trauma patient transfer. Overall, the author
27 recommends further research incorporating better study designs, larger sample size, and a focus
28 on incorporating smartphone technology (14).

29 Another study also presented concerns about the effectiveness and cost-effectiveness of
30 telemedicine, describing most telemedicine studies as methodologically inadequate before-and-
31 after studies that often fail to examine patient outcomes, and instead focus on feasibility and
32 convenience for patients (15). Additionally, the author stated there may be potential unintended
33 consequences related to the complex interpersonal and interprofessional relationships within the
34 health care profession because telemedicine compels patients to accept medical advice without
35 the benefit of in-person consultation, compromising patient trust and rapport. The study further
36 suggested that research must examine the crucial issue of context—not only whether
37 telemedicine works—but also how, when, and under which circumstances it works best (15).

38 **RECOMMENDATIONS**

39 More research must be conducted to determine whether prehospital time is significantly related
40 to patient outcome following motor vehicle collisions. If this research determines that prehospital
41 time is crucial and must be reduced as much as possible, there are several ways to achieve that
42 goal.

43 The time between the incident and EMS notification can be reduced through the
44 implementation of automatic crash detection technologies in vehicles with the ability to
45
46

1 accurately estimate injury severity and directly communicate with EMS dispatchers. These
2 technologies could also improve triage by notifying dispatchers when specialized services such
3 as vehicle extraction are necessary (2). This would prevent dispatchers from sending under-
4 equipped EMS vehicles to the scene and would reduce overall prehospital time. Triage can also
5 be improved by fully implementing Next Generation 911 throughout the nation so that more
6 detailed information can be provided to EMS responders before they reach the crash scene.
7 Telemedicine could also improve triage and on-scene patient treatment by allowing more
8 specialized medical professionals to provide input on the proper course of patient care. However,
9 further research is necessary before this can be determined.

10 When reducing response times, it is also necessary to address secondary crashes
11 involving emergency vehicles. To address the problem of a lack of understanding on the part of
12 many drivers in response to visual and audible signals from emergency vehicles, establishing and
13 enforcing a complete stop rule at intersections and at traffic signals when requesting the right-of-
14 way could prevent such secondary crashes (13).

15 A number of strategies have been developed to reduce response time—the time between
16 EMS dispatch and the arrival of the EMS crew at the scene. There are two main solutions to
17 reduce EMS response time: having more EMS vehicles in service at the same time, or
18 positioning the existing vehicles so that they have better access to emergencies (16). Because the
19 former involves substantial financial costs, research has focused on ways to locate EMS vehicles
20 more efficiently. This research includes dynamic load-responsive ambulance deployment (17),
21 discrete event simulations (18), decision support systems (19), and geospatial-time analysis of
22 ambulance deployment (20). These strategies all involve using retrospective data, GIS
23 information, and various models to determine where and when to locate ambulances. For
24 example, Gonzalez found that when rural ambulance station locations were moved from the area
25 of highest population concentration to areas with high motor vehicle collision rates and/or major
26 roads, EMS response times to motor vehicle collisions decreased (21).

27 Response time could also be decreased by making it safer for EMS vehicles to travel
28 quickly using sirens and lights. This could be achieved by mandating that EMS vehicles have
29 collision avoidance and other safety systems installed (2). The installation of vehicle-to-
30 infrastructure communication technology, such as road condition warning systems, would allow
31 EMS vehicle drivers to adapt their routes according to real-time traffic and avoid areas where a
32 collision would be more likely (2).

33 Finally, the transport time between crash scene and hospital could be reduced. Making it
34 safer for EMS vehicles to travel quickly could also reduce transport time. Another way to reduce
35 transport time would be to locate trauma centers strategically so that there is a Level 1 or 2
36 trauma center within one hour of any location in the nation; this could be accomplished through
37 the regionalization of EMS agencies (2). Finally, transport time may become less crucial if
38 treatment can be effectively administered during the trip through the use of telemedicine.

39 **CONCLUSION**

40 Although further research is necessary, reducing prehospital time may improve patient outcomes
41 following motor vehicle collisions. Prehospital time consists of the time between the incident and
42 EMS notification, the time between EMS dispatch and arrival on scene, the time spent at the
43 scene, and the time spent traveling from the crash scene to the hospital. Each of these time
44 periods can be reduced, although the benefit relative to the cost of doing so has not yet been
45 determined.
46

1 **The authors confirm contribution to the paper as follows: study conception and design: S.**
2 **Doggett, D. Ragland; data collection: S. Doggett; analysis and interpretation of results: S.**
3 **Doggett, D. Ragland; draft manuscript preparation: S. Doggett, G. Felschundneff. All**
4 **authors reviewed the results and approved the final version of the manuscript.**

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