Advanced prehospital resuscitative care: Can we identify trauma patients who might benefit?

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BACKGROUND: Uncontrolled truncal hemorrhage remains the most common cause of potentially preventable death after injury. The notion of earlier hemorrhage control and blood product resuscitation is therefore attractive. Some systems have successfully implemented prehospital advanced resuscitative care (ARC) teams. Early identification of patients is key and is reliant on rapid decision making and communication. The purpose of this simulation study was to explore the feasibility of early identification of patients who might benefit from ARC in a typical US setting.

METHODS: We conducted a prospective observational/simulation study at a level I trauma center and two associated emergency medical service (EMS) agencies over a 9-month period. The participating EMS agencies were asked to identify actual patients who might benefit from the activation of a hypothetical trauma center-based ARC team. This decision was then communicated in real time to the study team.

RESULTS: Sixty-three patients were determined to require activation. The number of activations per month ranged from 2 to 15. The highest incidence of calls occurred between 4 PM to midnight. Of the 63 patients, 33 were transported to the trauma center. The most common presentation was with penetrating trauma. The median age was 27 years (interquartile range, 24–45 years), 75% were male, and the median Injury Severity Score was 11 (interquartile range, 7–20). Based on injury patterns, treatment received, and outcomes, it was determined that 6 (18%) of 33 patients might have benefited from ARC. Three of the patients died en-route to or soon after arrival at the trauma center.

CONCLUSION: The prehospital identification of patients who might benefit from ARC is possible but faces challenges. Identifying strategies to adapt existing processes may allow better utilization of the existing infrastructure and should be a focus of future efforts. (*J Trauma Acute Care Surg.* 2021;91: 514–520. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

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Hemorrhage remains the most common cause of preventable death after injury.[1–3] Preventing such fatalities requires rapid control of hemorrhage and replacement of lost blood.[4] The typical approach to trauma care in most areas of the United States has been for emergency medical services (EMSs) to limit time on scene, rapidly drive or fly patients to a trauma center, and rapid evaluation by the trauma team in the emergency department (ED), followed by surgical control of hemorrhage in the operating room.[5,6] The results of this strategy are relatively disappointing. The literature shows that most patients will die within 30 minutes of their injury.[7,8] Time from injury to hospital arrival is a median of 45 minutes or longer, and the time from injury to hemostasis averages 2.1 hours.[3] If lives are to be saved, successful interventions must occur prehospital.

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The notion of early truncal hemorrhage control and blood product transfusion, at the point-of-injury or en-route to the hospital, is therefore attractive.[9,10] However, noncompressible torso hemorrhage, the most common cause of death, usually requires advanced resuscitative techniques in addition to blood product resuscitation (including abdominal aortic and/or junctional tourniquets, resuscitative endovascular balloon occlusion of the aorta [REBOA], or resuscitative thoracotomy), which are not readily available in the prehospital setting.[11,12]

Many European countries, as well as a select few areas in the United States, have successfully implemented prehospital care teams, often led by physicians, advanced paramedics, certified registered nurse anesthetists, and/or nurses, which offer these time-critical advanced resuscitative care (ARC) interventions.[13–16]

Developing and operating such services are challenging because the vast majority of injured patients do not need these specific interventions. Dispatching this asset to all injury scenes will not be the best use of a scarce resource. Thus, advanced care teams must be dispatched to those scenes where they may make the most difference in outcome. The time required to launch these teams, which will often be based at the trauma center or regional EMS station, needs to be balanced with the time required to transfer to the hospital. Hence, to effect the most difference, they should arrive close to the same time as regular EMS services to avoid any unnecessary delays.

Deciding when to launch a team is therefore a critical part of the process. In many countries outside the United States, EMS dispatch services are centralized in large call centers (also known as public safety answering points [PSAPs]), which have dedicated and experienced paramedics or doctors listening to incoming 911 calls. They may additionally ask callers questions and in some regions use telemedicine technology to decide when to deploy teams. The Greater London area (population of 12 million), for example, is served by a single call center. Similarly, the Scottish Ambulance Service has just three ambulance control centers that serve the entire country (population of 5.4 million or 1 PSAP per 1.8 million residents).

With some exceptions, PSAPs in much of the United States, in contrast, are smaller and decentralized. The National Emergency Number Association reports that there are around 6,100 PSAPs in the United States[17] (B. Ertl, personal communication, August 5, 2020) or 1 PSAP per 54,000 population. Jefferson County in Central Alabama (population of 656,573) has 15 call centers[18] (1 PSAP per 43,771 population), often staffed by only a small number of dispatchers with limited training. Placing dedicated EMS personnel in each of these PSAPs at all times to screen calls would be expensive and inefficient.

The purpose of this study was to explore the feasibility of early identification of patients who might benefit from ARC interventions in a typical US setting.

PATIENTS AND METHODS

Design

This was a prospective observational/simulation study.

Setting

The study was conducted at University of Alabama at Birmingham (UAB) Hospital, the only level I trauma center in the region, and two associated EMS agencies, Center Point Fire District (CPFD) and Bessemer Fire Department (BFD), between January and September 2019. University of Alabama at Birmingham Hospital is located in the City of Birmingham, in Jefferson County, Alabama, with a population of approximately 1.15 million people in its metropolitan area. There are currently 43 EMS agencies that serve the Jefferson County area. Center Point Fire District, in the northeastern part of the metro area, serves a population of approximately 70,000 in roughly 65 square miles covering the municipalities of Center Point, Clay, and a large portion of Pinson as well as areas of unincorporated Jefferson County in the northeastern quadrant. Bessemer, served by BFD, is located in the southwestern part of the metro area and has a population of 26,538. The study was approved by the UAB Institutional Review Board.

Case Identification and Data Collection

We asked the two participating EMS agencies to notify the trauma center, in real time, when they would ask a hypothetical physician-led prehospital care team, based at UAB, to be launched. For the purpose of this study, the agencies were advised that the team would have the following clinical capabilities: advanced airway management, advanced circulatory access, prehospital whole blood transfusion, endovascular control of hemorrhage (using REBOA), and resuscitative thoracotomy.

The agencies used two different approaches. Center Point Fire District used a cellphone-based application called "ACTIVE911" (Active911, Inc., Corvallis, OR) to push information obtained by dispatchers from the original 911 call to the CPFD Battalion Chief. On receipt, the battalion chief, an experienced paramedic, would then make an assessment of whether the physician-led prehospital care team would be asked to attend (if such a team were available) and notionally request its presence by emailing the study coordinator (providing a time stamp of when the decision was made). Bessemer Fire Department took a different approach. They provided PSAP dispatchers with details of the notional capabilities of the team, a list of possible clinical scenarios where launching the team should be considered (for example, patients with abdominal gunshot wounds who are losing consciousness; a patient with a stab wound to the chest who does not have a pulse; a patient crushed under or in a vehicle; or a mass public shooting incident, which is being attended by law enforcement). If the dispatcher felt that dispatch of the team was justified, they would immediately email the study coordinator in the same way.

On receipt of the notional team activation, the in-hospital study team then screened trauma calls regarding inbound patients for matching characteristics, to link the prehospital and in-hospital data. The appropriateness of notional team activation, based on prehospital and in-hospital information, as well as the likely benefit of prehospital team activation, were assessed on a consensus basis by three of the senior investigators (J.O.J., J.B.H., and Z.Q.).

Analysis

Data were collated in an encrypted, password-protected Excel spreadsheet (Microsoft Corporation, Redmond, WA). Statistical analysis was carried out using Stata 16.0 (StataCorp, College Station, TX).

The estimated travel time from the trauma center to the incident locations was calculated using arcGIS (ESRI, Redlands, CA). Latitude and longitude were obtained from EMS reports. Start time for the transport team was based on time of activation. Ground travel time was calculated based on the fastest route, at "lights and siren" speed. Air travel time was calculated estimating a helicopter cruising speed of 246 km/h (typical of currently used aircraft), assuming a helicopter based at the trauma center, with an additional 10 minutes added for the aircraft to get airborne.

RESULTS

Characteristics of the Study Population

During the 9-month duration of the study, we received 60 notifications from CPFD and 3 notifications from BFD. Figure 1*A* shows a timeline of when the notifications were received during the study period. This shows variations during the study period, with peaks in February, June, and July. The distribution of the time of the day when the simulated callouts took place is shown in Figure 1*B*. Simulated callouts most commonly occurred in the evenings with the highest incidents of calls between 4 PM to midnight. The triage time at the EMS agency was short, with 44 (70%) of callouts occurring within 2 minutes of the initial 911 call.

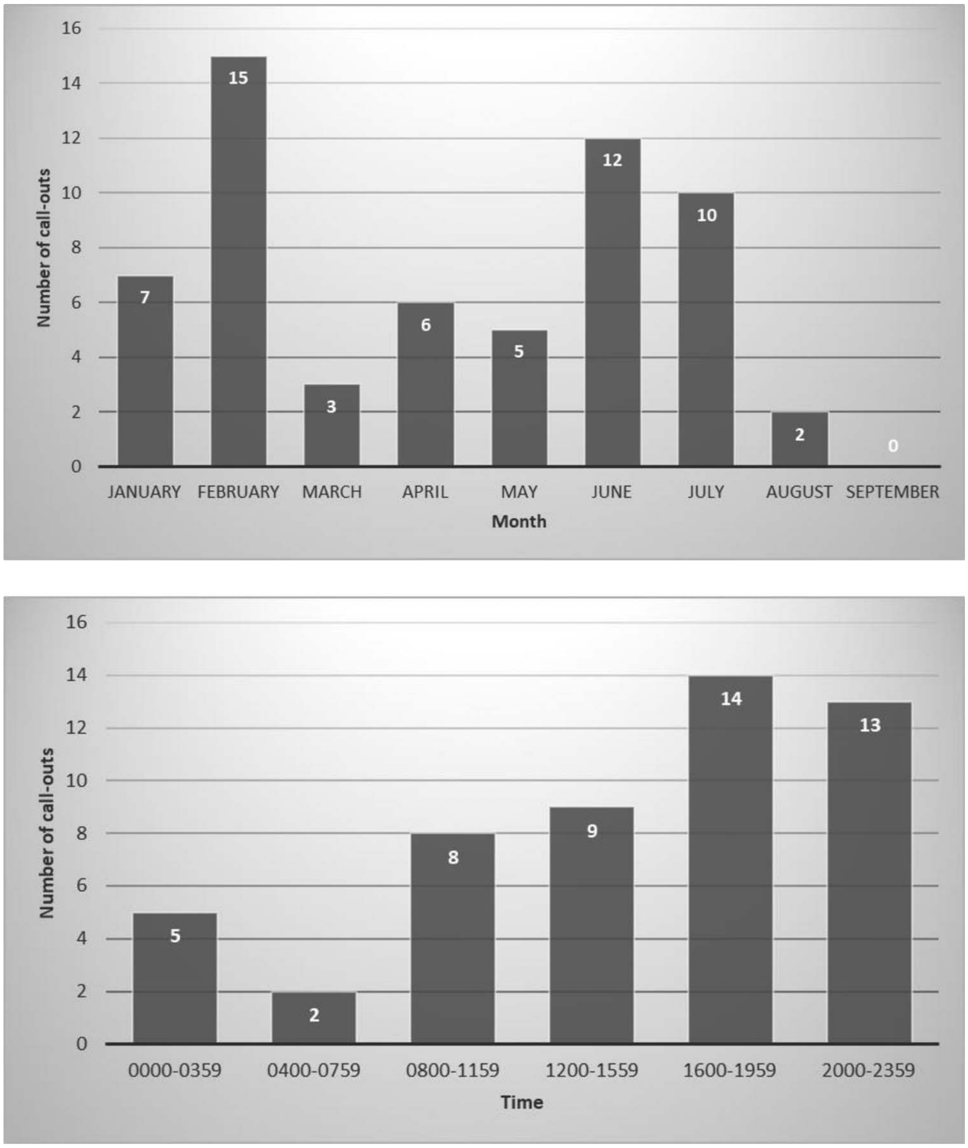

Figure 1. (*A*) Variations in number of callout pages over the study period. (*B*) Variations in number of callout pages throughout day.

Table 1 shows the mechanism of injury, based on only the prehospital information, for both EMS agencies. Fifteen were related to motor vehicle collisions, two involved pedestrians or cyclists struck by vehicles, five related to penetrating injuries, and one followed blunt assault. Detailed prehospital data to determine injury mechanism were not available for 40 patients. At this stage, many of the notifications consisted of information that would be valuable to the battalion chief or dispatchers (such as units in attendance) but not easily interpretable by the researchers. Thirty-three (53%) of the notional callouts resulted in the patient being taken to the ED at UAB; the remaining 30 patients (47%) were presumed to have been taken to a different center because of down-triage or deemed not to require hospital care at all.

TABLE 1. Mechanism of Traumatic Injury Determined by Information on Callout Page (n = 63)

Mechanism	No. Simulated Callouts
Motor vehicle collisions	15
Pedestrian/cyclist struck by vehicle	2
Penetrating injuries	5
Nonpenetrating assault	1
Unable to determine	40

Patients Who Were Taken to Trauma Center

The median age of the 33 patients who were taken to UAB was 27 years (interquartile range [IQR], 24–45 years). The majority of patients were male (n = 25, 75.8%), and almost all patients were transported by ground ambulance (n = 32, 97.0%), with only one patient being taken by helicopter. The median Injury Severity Score was 11 (IQR, 7–20). There were more activations for penetrating (n = 20, 60.6%) as compared with blunt (n = 13, 39.4%) trauma. The median time from simulated callout to arrival in the ED was 40 minutes (IQR, 32–49 minutes). Scene vital signs were not available for 15 (45.5%) of the patients, and only 10 patients (30.3%) had respiratory rate, oxygen saturations, heart rate, blood pressure, and Glasgow Coma Scale score recorded. The median respiratory rate was 18 breaths per minute (IQR, 16–20 breaths per minute), median heart rate 98 beats per minute (IQR, 79–122 beats per minute), and median systolic blood pressure was 140 mm Hg (IQR, 130–162 mm Hg) (Table 2). Three patients (5%) were intubated at the scene, with two requiring concurrent CPR.

Table 3 shows the vital signs on arrival in the ED. The median respiratory rate was 20 breaths per minute (IQR, 18–22 breaths per minute), median heart rate was 93 beats per minute (IQR, 77–103 beats per minute), and median systolic blood pressure was 135 mm Hg (IQR, 106–150 mm Hg). During the ED trauma assessment, a further 6 patients (10%) required intubation. Other interventions performed in the ED were thoracotomy (n = 1), insertion of chest tube (n = 4), blood transfusions (n = 3), and use of vasopressors (n = 1). Operative intervention was ultimately required for 23 patients (38.3%) with some requiring multiple procedures. Four patients died, all from penetrating trauma. Three of the deaths occurred within 6 hours of receiving the callout page, and the fourth, several months later.

Likely Benefit of Team Activation

Based on patient injury patterns and ultimate outcomes, the three assessors determined, by consensus, that 6 (10%) of the patients might have benefited from advanced prehospital care, had such a service been available. The notifications for all of these patients were received from CPFD.

Three of these six patients died. The first (patient 2, Table 4) had suffered a gunshot wound to the face and neck. Intubation was attempted at the scene but was made difficult by bleeding into the oropharynx and airway. Although intubation was ultimately successful, the patient suffered a cardiac arrest, probably as a result of both blood loss and hypoxia. The patient eventually died of an anoxic brain injury and multiorgan failure several weeks later. The patient might have benefitted from a surgical airway in the prehospital setting (which is not currently within the scope of practice of paramedics in Alabama).

The second patient who died (patient 4, Table 4) had suffered a transthoracic gunshot wound. He was found pulseless on EMS arrival, and ACLS was initiated. Although there was a brief period of return of spontaneous circulation, he suffered a further cardiac arrest en-route to the trauma center, and resuscitation efforts were stopped after no cardiac activity was seen on ultrasound in the ED. There was no postmortem examination. The patient might have benefitted from prehospital thoracotomy and transfusion, although it is possible that the injuries would not have been treatable.

The third patient who died (patient 5, Table 4) suffered multiple gunshot wounds to the abdomen. He was normotensive on scene but arrived in the ED in extremis and underwent resuscitative thoracotomy and, subsequently, laparotomy. He was found to have injuries to an iliac artery and iliac vein, liver, and small bowel. Postoperatively, he was taken to the intensive care unit but suffered a cardiac arrest shortly after, from which he could not be resuscitated.

Of the three survivors who might have benefited from prehospital ARC, one (patient 1, Table 4) had suffered multiple machete injuries and was profoundly hypotensive on arrival in the ED, requiring emergent intubation and transfusion, followed by surgery to the extremities. There was no truncal hemorrhage. The patient might have benefitted from prehospital blood transfusion. The second survivor (patient 3, Table 4) had been shot in the chest and was profoundly hypotensive (systolic blood pressure, 54 mm Hg) on arrival in the ED, requiring thoracotomy and neck exploration for a right subclavian artery transection with associated hemothorax. The patient might have benefitted from prehospital transfusion and, possibly, thoracotomy (although gaining control of a proximal subclavian artery injury is clearly difficult). The third survivor (patient 6, Table 4) had an abdominal gunshot and then was also involved in a motor vehicle collision. The patient was hypotensive on arrival in the ED (systolic blood pressure, 74 mm Hg), requiring intubation, chest tube insertion, and massive transfusion, followed by laparotomy, where he was found to have a liver injury. He might have benefitted from prehospital transfusion and, possibly, REBOA.

TABLE 2. Vital Signs at Scene (Total, n = 63)

Vital Sign	No. Patients With Recorded Values	Median (IQR)
Respiratory rate, breaths/min	10	18 (16–20)
Oxygen saturations, %	16	98 (97–99)
Heart rate, beats/min	18	98 (79–122)
Systolic blood pressure, mm Hg	18	140 (130–162)
Glasgow Coma Scale score	17	15 (15–15)

TABLE 3. Vital Signs on Arrival in ED (Total, n = 63)

Vital Sign	No. Patients With Recorded Values	Median (IQR)
Respiratory rate, breaths/min	59	20 (18–22)
Oxygen saturations, %	60	99 (96–100)
Heart rate, beats/min	60	93 (77–103)
Systolic blood pressure, mm Hg	62	135 (106–150)
Glasgow Coma Scale score	60	15 (14–15)

Geospatial Analysis

Time to scene data were available for 31 of the patients who were transported to the ED. Location data were missing for two of the patients. The median predicted ARC travel time to reach the incident locations by ground was 22.9 minutes (IQR, 22.1–23.9 minutes). The corresponding median air travel time was 14.6 minutes (IQR, 14.3–14.9 minutes). Of the six patients who might have benefitted from an ARC team, five had geocodable incident location data. Median predicted ground travel time was 23.5 minutes (IQR, 22.1–27.5 minutes), and median predicted air travel time was 14.6 minutes (IQR, 14.3–15.9 minutes). In all cases, the ARC team would have arrived at the scene after arrival of the EMS team.

DISCUSSION

High-level estimates suggest that there are approximately 30,000 to 60,000 preventable hemorrhage-related deaths in the

TABLE 4. Characteristics of Patients Who Might Have Benefitted from Advanced Prehospital Care

Characteristic	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Mechanism	Machete	GSW	GSW	GSW	GSW	GSW + MVC
Injuries	Multiple extremity injuries	Facial fractures C-spine fracture	Subclavian artery transection	Transthoracic gunshot wound	Iliac artery and vein, small bowel, liver	Hemothorax, liver
Injury Severity Score	17	45	9	42	17	32
Vital signs at scene						
Respiratory rate, breaths/min	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded
Oxygen saturations, %	Not recorded	Not recorded	Not recorded	Not recorded	89	Not recorded
Heart rate, beats/min	Not recorded	Not recorded	Not recorded	50	149	Not recorded
Systolic blood pressure, mm Hg	Not recorded	Not recorded	Not recorded	Not recorded	120	Not recorded
Glasgow Coma Scale score	Not recorded	Not recorded	Not recorded	Not recorded	4	Not recorded
Lifesaving interventions at scene/en route	None recorded	Intubation	None recorded	Intubation, CPR	None recorded	None recorded
Vital signs in ED						
Respiratory rate, breaths/min	22	Ventilated	28	Ventilated	Not recorded	30
Oxygen saturations, %	95	99	78	Not recorded	100	100
Heart rate, beats/min	140	99	142	CPR	95	138
Systolic blood pressure, mm Hg	70	119	54	CPR	0	74
Glasgow Coma Scale score	15	2T	14	2T	3	11
Lifesaving interventions in ED	Intubation, transfusion	Transfusion	Intubation, chest tube insertion, transfusion	None	Intubation, chest tube insertion, ER thoracotomy	Intubation, transfusion, chest tube insertion
Further operative treatment	Multiple extremity operations	Tracheostomy, gastrostomy	Thoracotomy	None	Laparotomy	Laparotomy
Outcome	Survived	Died	Survived	Died	Died	Survived
Possible benefit of advanced prehospital care	Transfusion	Surgical airway, transfusion	Transfusion	Thoracotomy, transfusion	Thoracotomy, transfusion	Transfusion, REBOA

CPR, cardiopulmonary resuscitation; GSW, gunshot wound; MVC, motor vehicle collision.

United States per year.[1,19] A more granular analysis of data from our area has shown that, in 2017, around 38 prehospital trauma deaths (12% of all prehospital trauma deaths) in Jefferson County may have been preventable with ARC.[6] Analyses from other settings have yielded similar results. Prehospital hemorrhage control (particularly when from noncompressible sources) and resuscitation is conceptually attractive, particularly in settings with high numbers of penetrating and ballistic injuries, such as the United States. However, the implementation of such strategies may be more complex than expected.

Delivering medical care in the field is challenging in itself, requiring a high level of training and quality assurance. The capabilities of our theoretical ARC team (advanced airway management, advanced circulatory access, endovascular control of hemorrhage, and resuscitative thoracotomy) were based on a local needs assessment. Prehospital blood transfusion does not necessarily require a physician and is offered by some EMS agencies in Alabama. In addition, some paramedics can deliver advanced/surgical airway management (although not currently in Alabama). Resuscitative endovascular balloon occlusion of the aorta could possibly be performed by paramedics, but prehospital thoracotomy will, most likely, remain a procedure that requires a physician.

However, a prehospital care team, no matter how skilled, can only deliver advanced care if it is called to the scene for the right patient at the right time. Our study shows that organizational issues, in particular, appropriate patient identification, are as critical as the delivery of care. The current number and disparate nature of the dispatch infrastructure in the United States does not allow us to use the same approaches as in other countries. This study attempted to simulate the callout of a hypothetical, physician-led, prehospital care team, based at UAB hospital. By using Battalion Chiefs and dispatchers, we had hoped that we would be able to identify those patients who might benefit from ARC. Our results demonstrate only partial success. We found that around 10% of patients identified in this cohort might have truly benefited from ARC, indicating overtriage. However, this is not a shortcoming, as a degree of overtriage is inevitable and appropriate to capture those patients who definitely require ARC. As a system matures, this overtriage may become refined. In addition, we did not account for patients who had arrived the hospital that may have benefitted from prehospital ARC, those who were simply not identified by the field personnel, or those who died on scene. Hence, the true number that could have benefitted may have been higher. Finally, there were also a large number of patients who either did not need hospital or trauma center care at all, or had relatively minor injuries, highlighting the importance of appropriate utilization of what would be a highly skilled resource.

Prehospital decision making is difficult, because it is based on limited information and made under pressure. The process is made even more difficult when the information is relayed by others. The results of our simulation study suggest that additional measures will have to be put in place to improve the early effective identification of patients who might benefit from an ARC team. Since this decision making is dependent on information provided, often by laypersons, on the initial 911 call, it is imperative to shift the paradigm of dispatching of appropriate resources. This can be modeled on existing advanced dispatch mechanisms seen internationally. These include London's Air Ambulance, one of the leading providers of physician-led prehospital care; the Scottish Ambulance Service; the Services d'Aide Médicale Urgente de Paris; and the Sydney Helicopter Emergency Medical Service, which use a model of call screening in the dispatch center by an experienced senior paramedic or prehospital physician.

Although some physician-delivered prehospital services, such as the MD1 program in New Jersey, do exist in the United States, most areas probably face similar problems to those identified in our study—a large number of small, dispersed communication centers, with disparate infrastructures and processes.

This is likely to be a significant barrier to the development of advanced prehospital care services and prehospital hemorrhage control in the United States. Combining call centers and centralizing resources would be expensive in the short term and require considerable commitment from stakeholders but might actually be cheaper in the longer term. The alternative is to continue to refine criteria that could be provided, along with the appropriate training, to dispatchers or other decision makers. Ultimately, this would lead to an "autolaunch" of the ARC team in appropriate cases as occurs with some helicopter EMS programs.[20]

One of the major weaknesses of this study is that, although there is interest in developing one, a physician-led prehospital care team does not currently exist at UAB. Maintaining a group of clinicians who are available to deploy at very short notice (within minutes) would not be easy. Presently, there are two trauma surgeons in-house at all times. Depending on workload, an ARC team might draw on one of these surgeons. However, this would impact on other clinical duties. A team staffed by dedicated clinicians would be preferable but would have clear resource implications, particularly if a helicopter were also to be maintained. In 2019/2020, London's Air Ambulance service had an expenditure of US $14.6 million (£10.5 million). Setting up such a service would also require extensive training. It is likely that further justification of need is required.

A simulation study, even when conducted in real time, does not impart the same "feedback," positive or negative, as the actual launch of a team. Engagement with such studies is often problematic, as shown by the fact the BFD only contributed three cases. Another weakness of the study is that the dispatchers at BFD did not receive formal training in case identification. We therefore believe that there would be value in a follow-on study, with a focus on training (including retraining) of dispatchers and decision makers, engagement, and feedback. There would also be value in identifying patients at the hospital, who might have benefited from advanced prehospital care but were not identified by EMS services, and feeding this information back to dispatchers and other EMS personnel. In addition, we do not have further information on the 30 patients for whom activations were received but were not taken to UAB trauma center. This is a consequence of the study's design. Similarly, it would have been helpful to record at least some details of patients taken to the trauma center by the two participating agencies, for whom no activation was received. Again, this was not considered at the inception of the study. We would like to address both of these issue with a follow-up study. Lastly, it would also be useful to include additional EMS agencies, but this would require more resources.

Nevertheless, our study also has several strengths, the most important being that it simulates and examines the decision-making process in real time. It is relatively straightforward to retrospectively examine medical records and postmortem reports to conclude, with the benefit of hindsight, who might have been helped by ARC. Making such decisions based on a few lines of text recorded by a dispatcher who took a call from a distressed bystander is more difficult.

CONCLUSION

Prehospital hemorrhage control is conceptually attractive but requires equipment and skills that are not readily available. Dispatching specialist teams with advanced clinicians intuitively makes sense and has been shown to benefit patients in a number of settings. Our study demonstrates the challenges involved with identifying appropriate cases in our decentralized prehospital dispatch system, prompting a need to substantial reconfiguration and development to optimally utilize such a resource.

AUTHORSHIP

J.O.J., J.B.H., D.R., S.L.C., Z.Q., P.A., and S.W.S. conceptualized the project. A.I., K.J., W.W., R.H., R.L.G., and J.O.J. were involved with the data collection and analyses. A.I., J.O.J., Z.Q., and J.B.H. wrote and revised the first draft. All authors were involved in the review and revision of the final article.

DISCLOSURE

The authors declare no conflicts of interest.

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