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REVIEW ARTICLE

Prehospital ultrasound as the evolution of the Franco-German model of prehospital EMS

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Abstract

Purpose To evaluate, throughout model analysis and evaluation of existing literature and personal experience, which can be the benefits of routine performance of prehospital ultrasound in the different models of prehospital emergency medical service.

Methods The existing literature was reviewed.

Conclusions The ultrasound can be a very valuable asset in both the Anglo-American and the Franco-German models. In the latter, however, its role is further emphasized since US-enhanced on-spot early diagnosis performed by the physician can be beneficial to the whole system and not just the single patient.

Keywords Ultrasound · Prehospital · EMS · Model

Introduction

Prehospital emergency services are a relatively recent development of modern medicine. Although dedicated means of transport for the wounded have been employed in the past, it is only in recent years that emergency medical systems (EMS) have been carefully devised as independent sectors of health care. An Emergency Medical Service (EMS) can be defined as "a comprehensive system that provides the arrangements of personnel, facilities and equipment for the effective, coordinated and timely delivery of health and safety services to victims of sudden illness or injury" [1]. All EMS developed throughout the world, albeit with slight differences, can be roughly classified into two main models. These models were introduced since 70s, derive their name from the countries of first development and have distinct features, due to a different principle of care provision. The two models of pre-hospital care are the Anglo-American and the Franco-German model. The Anglo-American model (AAM) provides health care throughout ambulances staffed by technicians (usually referred to a "EMT" or "paramedic") according to the principle of providing in-hospital care in the shortest possible time. The Franco-German model (FGM) relies on medical-staffed ambulances, following the idea of bringing the hospital to the patient rather than or before bringing the patient to the hospital which obviously often occurs.

It is our aim to evaluate which can be the role of a powerful diagnostic tool, such as prehospital emergency ultrasound (PHEUS) in the evolution of prehospital emergency, especially in the Franco-German model of EMS. To assess which of the two EMS models is globally most effective is a challenging task, addressed but yet unresolved [2, 3] because of unconclusive results, and is beyond the scope of the present article.

The two models

As previously mentioned, the two main models are the Anglo-American and the Franco-German. As their names tell, the former has developed in English-speaking countries whereas the latter has spread in continental Europe. The principles underlying the organizational models are commonly nicknamed "scoop and run" for the AAM and "stay and play" for the FGM. The mainstay of the AAM is bringing the patient inside a hospital to provide definite care in the smallest time interval. This is accomplished by

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having a large number of ambulances usually staffed with technicians, commonly called as "paramedics", trained to perform basic and lifesaving maneuvers which bring the patient to the nearest hospital. Invasive maneuvers and therapy, unless strictly life-saving, are thus delayed to in-hospital care. Main focus of the EMS is minimizing transport times, providing on-site life-saving maneuvers and devoting resources chiefly to increase admission and treatment capabilities of emergency departments. Usually, in the AAM response to calls is based on a single-tier or two-tier system. Telephone contact with a physician is available for paramedics in action for advice on treatment. Physicians are instead commonly involved in inter-hospital (secondary) transport, often performed by helicopters. Expeditious secondary transport is consequently largely practiced, given the number of patient who require definitive care in a different hospital form the one of first admission. Countries that adopt this type of EMS include United Kingdom [4], United States [5], Canada [6], Japan [7], South Africa [8], New Zealand and Australia and, unexpectedly for its geographical location, Holland [9].

On the contrary, the Franco-German model is built up to bring as soon as possible extended care to the patient, according to the "stay and stabilize" paradigm. This is done with physician-run ground and air ambulances coordinated by a dispatch centre in a multi-tiered response to calls, which at least in Italy, includes paramedic-run, nurse-run, physician-run ambulances and helicopters. The presence of a physician allows in-the-field diagnosis, improved care quality during transport, and targeted referral of patients. This is especially valuable in a hub-and-spoke model of emergency. This approach entails longer time on scene and should warrant, if well practiced, clinical stabilization of the patient, if achievable, prior to transport to the most suitable hospital. Since patients are commonly referred to the most suitable rather than simply to the nearest hospital transport times can be greatly increased to suit the patients needs, should closer hospitals have inadequate or overcrowded facilities. En route therapy and monitoring are thus everyday practice. Another peculiar feature of this model is the possibility, with physicians practicing clinical judgement, to downgrade the estimated severity of the problem. Once established the non-urgent clinical condition of the patient, the latter can either be left at home and advised to seek further help from the family physician or undergo delayed transport to the hospital with a lower-tier ambulance (e.g. an ambulance without medical staff on board), thus freeing a high-level resource to be employed in another mission. Lastly, this model allows occasional direct admission to hospital facilities (e.g. the cath lab in case of a STEMI) bypassing the emergency department thus sparing time. The countries that have organized their EMS according to this model include Germany [10, 11], France [12], Italy, Spain, Greece [13], Malta [14] and Austria [15].

Interestingly, the Nordic countries [16] have a hybrid situation, since the adopted AA model is locally modified by incorporation of some physician-run ground and air ambulances.

The main differences between the two systems are summarized in Table 1.

It is quite clear that this model requires both a comprehensive set of therapeutic options and the widest possible collection of relevant diagnostic tools. The standard equipment of a medical-run ambulance usually includes a 3-lead and 12-lead-ecg, pulse oxymeter, blood glucose meter and blood pressure unit. Some manual defibrillators, beyond ECG reading, also provide oxymetry and capnography wave. Recently, portable instant-result kits for elementary blood chemistry have been introduced on ambulances. Apart from the mentioned tools, the burden of the diagnosis still rests mainly on the signs and symptoms elicited by physical examination of the patient. However, the reliability of physical examination is highly questionable [17–19], let alone in a noisy and badly lit environment. Thus, in this model, the physician is in constant need of further diagnostic information, since he lacks many of the features available in the hospital, above all the imaging technique. It is our belief that this information, or at least part of it, can be yielded by prehospital sonography.

Prehospital ultrasound

Pre-hospital emergency is a field of medicine that requires swift response to suddenly arisen unexpected problems that must be solved in a expeditious and appropriate manner. To

Table 1

Franco-German model	Anglo-American model
More treated on scene, few transported to EDs	Few treated on scene, more transported to EDs
Cases attended by a physician, nurse and paramedic	Cases are attended by paramedics
Possible transport to hospital wards i.e: bypassing EDs	Direct transport to EDs
Usually part of public health organization	Usually part of public safety organization
Immediate extensive care	Delayed extensive care
Referral to most suitable hospital	Referral to closest hospital
Focus on diagnosis and treatment	Focus on swift transport to hospital
Immediate high-level care	Delayed high-level care
Possible transport to hospital facilities i.e: bypassing EDs	Only direct transport to EDs
Prolonged transport time	Short transport time
Multi-tiered response	Usually single or two-tiered response

provide optimal care the physician requires a high degree of certainty about the diagnosis in order to take crucial decisions, and ultrasound alone can supply the evidence needed. Once limited to the radiologist room, ultrasound is now routinely practiced at the patient's bedside. To describe this particular use of ultrasound many terms have been coined to enhance the many relevant features of such practice (bedside, emergency, focused, critical).

No matter the name, this approach to ultrasound has been evolving dramatically in the recent years. The availability of small, battery operated portable machinery has brought ultrasound in the most remote areas and the most uneasy contexts among these, the patient's home and the ambulances. Some concerns did arise on technical feasibility, especially whether the environment can be a hindrance or utterly flaw the performance of ultrasound scanning. However, this issue has been addressed successfully. In particular, feasibility studies from many different countries have all reported that restricted space in vehicles, uncontrolled light, interference from avionic instruments and vibration from the engine, that potentially can mar the examination, can all be overcome. The only report of significant light interference was in a feasibility study conducted on non-medical sonographers with minimal training [20]. Perusal of existing literature shows clearly how studies focusing on technical feasibility, especially in airborne ambulances [21–27], hail from both countries adopting the AA model and from countries adopting the FG model, whereas clinical studies have been carried out mainly, with some exceptions [23, 28, 29], in countries adopting the FG model. However, it must be emphasized that some pilot studies in teaching ultrasound to non-medical personnel have been carried out in countries adopting the AA model where paramedic ultrasound project are under construction [20] and most of which have been presented as posters at the World WIN-FOCUS Congress in Sydney and published in the Journal of Critical Ultrasound.

Considering the FGM organizational model, the role and duties of the physician aboard an ambulance we can now review on the basis of existing literature, which is the possible role of ultrasound in such a model, refraining from speculation but focusing on applications supported by a sound basis. Some authors have already provided us with a thorough review of existing literature on the prehospital ultrasound [30, 31]. It is our aim to focus on which are the benefits that prehospital ultrasound can yield in an EMS, especially in a physician-run one.

Early diagnosis

As previously said, available diagnostic tools in the prehospital setting are scant and clinical examination of the patient, whose relevance is in itself already arguable, can be further flawed by environmental factors and thus may be deemed unreliable. Ultrasound allows speedy detection of some definite US findings ruling in or out major clinical problems. This enables a correct therapeutic approach from the very beginning. Many of these US features are quite easily identified even by non-expert sonographers, after minimal training [32–34]. Bedside ultrasound has been at first employed in trauma patients aiming at early detection of peritoneal free fluid as described by Rozicky et al. [35]. It has since then evolved encompassing the detection of haemothorax, haemopericardium and tamponade, and pneumothorax [36]. A fast, non-invasive examination providing all this information on spot capable of identifying bleeding site and roughly estimate hemorrhage is definitely a valuable asset. However, it is misgiving to focus emergency ultrasound on trauma patients only. In a preliminary survey to assess feasibility and technical necessities to implement prehospital ultrasound, carried out on the EMS of Torino, Italy, in a suburban area, a randomized series of ultrasound exams performed in prehospital setting yielded the startling result that out of 20 consecutive examinations the vast majority was carried out on medical patients and only one was performed on a trauma patient (unpublished). Recent developments in pleural and lung ultrasound allow in-the-field diagnosis of the main pleuropulmonary disorders, such as pneumothorax, pleural effusion, atelectasia, pneumonia and, most important, differentiation between the so-called "wet lung" and "dry lung" [37]. This provides the physician with a reliable tool to differentiate at a glance COPD exacerbation from pulmonary edema. Basic echocardiography is another asset of inestimable value for the physician in-the-prehospital setting. If all quantitative measurements are better left to the experienced sonographer, a quick-look evaluation of a cardiac scanning can give treasurable information, answering simple yes/no questions. Is the heart contracting normally? Are there enlarged chambers? Is there pericardial effusion? Most interestingly, there is growing evidence [38] that a quick-look evaluation (so called "eyeballing") of global cardiac kinesis is quite reliable in providing a rough estimate of the ejection fraction. Another topic on which ultrasound can supply crucial information with a startlingly simple technique is the filling status of the patient. A quick scan of the inferior vena cava can immediately give a precious clue on the estimate CVP. Combination of lung, heart and inferior vena cava imaging provides a powerful tool in establishing the underlying cause of a shock in a hypotensive patient. This leads the physician in taking decisions about fluid replacement, amine infusion or other therapy. All references mentioned above come from in-hospital setting, but we have no reason to doubt that their results would not apply to the prehospital environment.

Another promising application is the performance of out-of-hospital trans-cranial Doppler which can provide information about increased intracranial pressure otherwise unavailable. The technique has been recently demonstrated as feasible by Petrovic et al. [39] and further confirmed by Holscher et al. [40] also in the prehospital setting.

As clearly demonstrated by Lapostolle et al. [41] in their pioneering work, prehospital ultrasound is extremely useful in lowering the number of plausible diagnoses. The impact of ultrasound is most effective in cases with an intermediate degree of certainty of the diagnosis, since it can direct the physician's judgment by ruling in or out several clinical suspicions.

Ultrasound in cardiac arrest

An extremely demanding and time-dependent task of prehospital medicine is the management of cardiac arrest. In managing cardiac arrest, any variation in its management must be conformed to the existing international guidelines. Breitkreutz et al. [31] have brilliantly demonstrated how it is feasible to perform ultrasound during cardiopulmonary resuscitation, without affecting its quality and efficacy. In the treatment of cardiac arrest, ultrasound allows early detection of certain pathological findings that warrant immediate performance of life-saving maneuvers that otherwise could have to be performed on the basis of clinical suspicion only. Typical examples are the drainage of a pericardial tamponade, the administration of a thrombolytic agent in course of massive pulmonary embolism, fluid bolus in case of hypovolaemia, decompression of a tension pneumothorax [42–45]. It is of at most importance that the role of US in course of cardiac arrest has now been fully recognized by international guidelines [46, 47]. Another potential asset of ultrasound in course of cardiac arrest is its possible prognostic value. The issue of when to begin resuscitation (especially of unwitnessed cardiac arrests) and when to terminate resuscitative efforts is indeed a very delicate one, and any support from a diagnostic device is more than welcome. As first described by Blaivas et al. [48] and subsequently confirmed by other studies [49], the evidence of cardiac standstill at first ultrasound scanning is a absolute predictor of poor prognosis, regardless of the ECG rhythm. Patients presenting with a true asystole, i.e. absence of visible movement at ultrasound do not survive despite optimal resuscitation. Instead, direct visualization of persistent cardiac movement is definitely an indication to continue resuscitation as this is associated with a better outcome [50].

Improved patient staging and monitoring

Prehospital ultrasound can be extremely useful in assessing and monitoring the patient. For example, in a hypotensive or shocked patient the estimate of the filling status and of the response to fluid challenge are crucial information, usually unavailable without invasive techniques. These parameters can be rapidly assessed by measuring the end expiratory IVC diameter and the collapse index of the IVC. These data can be of particular value in the case of prolonged transport times, as occurs in remote areas, in both primary (target-to-hospital) o secondary (inter-hospital) transport. As said, should a fluid replacement therapy be started, repeat assessment of IVC parameters provides a cheap and reliable monitoring of response to fluid administration [22, 25]. The onset of a B-lines pattern at lung ultrasound is an early marker of initial volume overload and an indication to slow or stop fluid administration. In the ERC guidelines for Advanced Life Support [51], it is recommended to check blood pressure and look for signs of lung overload 10 min after fluid challenge to decide whether to continue fluid administration. Since many transports do exceed that timeline, physicians frequently need to perform such assessment. Clinical evaluation, in this case, is surely less reliable than US scan and yields late results.

Another check that prehospital rescuers are often required to perform is to control correct placement of the endotracheal tube. Incorrect placement of ET occurs occasionally and a correctly placed tube can be subsequently dislocated during transport. There is good evidence [52] that this check is feasible and reliable if performed by US, whereas all other methods, except $EtCO_2$ measurement, which is rarely available in the extreme settings, are not as dependable. The reliability of US assessment of ET tube placement has been assessed not only for physicians but also for prehospital care providers too [53].

Targeted referral of the patient

An early definite diagnosis is the first step of a diagnostic and therapeutic path that, at least in the FGM, leads the patient to the most suitable hospital. In a hub-and-spoke system, a doctor-staffed ambulance can bypass a spoke centre unfit to treat the patient and head straight to a higher-level facility that can provide definitive care, thus sparing valuable time. Both existing literature [54] and our experience suggests that this process can be greatly eased by ultrasound diagnosis. Ultrasound can readily identify the presence of life-threatening conditions, usually treated in by a specialist. A typical example is the presence of an aortic aneurysm with suspected rupture. A patient with a complaint of abdominal pain and a prehospital sonographic diagnosis of a dilated aorta can be righteously referred to a hospital with vascular surgery facilities even if it is not the closest available hospital.

Tailored selection of the mean of transport

By the same token, if an early diagnosis establishes the need to bring the patient to a distant admitting facility it may also help to decide how to transport the patient, by air or land ambulances. We can thus infer, even in the absence of supporting studies, on the basis of personal experience, that US can help in carrying out such decision.

Considering the example above, if a vascular surgery is not available in the immediate surroundings, ultrasound detection of an AAA in a shocked patient with abdominal pain justifies the deployment of a helicopter ambulance to collect the patient in the field to speed up its transport to a distant receiving hospital.

Although limited to trauma patients, existing literature confirms a beneficial effect of HEMS on severely injured patients [55] but in the meantime shows that many HEMS-transported patients usually undergo an overtriage phenomenon, i.e. have no critical injuries [56]. A tool to better assess if they are likely to benefit from HEMS transportation is thus well needed.

Improved communication and teamwork with admitting hospital

Walcher et al. [52] have demonstrated how prehospital ultrasound can improve treatment of the trauma patient. Most interestingly, they also found that the performance of an ultrasound scanning in the field had a significant impact also on the intra-hospital management of the patient. They observed that patients admitted with a prehospital FAST which had already identified intraabdominal bleeding, the time to the operating room was markedly reduced as compared to those with same traumatic lesion whose FAST exam was performed after hospital admission. The mean delay in these patients was 35 min, far more than average performance time for a FAST. It is not unlikely to hypothesize that, once prehospital ultrasound is established as a standard of care and sound quality assurance policies have been set up, a receiving hospital can direct the patient with positive FAST exam and stable haemodynamics straight to a second level imaging exam (CT, contrast-enhanced US) thus reducing time to diagnosis also in patients not requiring immediate surgery. Although cited literature deals only with trauma patients we believe that the same would occur for other surgical or medical patients.

Procedural support

Just as in the in-hospital setting, invasive maneuvers must sometimes be performed without delay in the pre-hospital arena. These procedures are inevitably performed blindly and can result in failure or carry high risks of complications, ranging from minor to fatal ones. Multiple attempts at a difficult procedure do increase the likelihood of a complication. Procedures which can be smoothed by ultrasound assistance are pericardial drainage, tension pneumothorax decompression and obtaining an IV access. All of these can be more easily and safely accomplished by ultrasound guidance, as demonstrated by intra-hospital practice.

In case of a shocked patient with a pericardial effusion with tamponade, drainage is mandatory. Ultrasound is useful not only in making the diagnosis but also in guiding the procedure: it has been demonstrated [57] that US guidance yields a higher success rate, lower complication rate and reduced number of attempts. This is mostly due to the fact that US guidance allows puncture in the dependent periapical region. Here the collection is usually abundant, closer to the thoracic wall with no interposing lung, myocardial walls are thicker and lacking major coronary vessels. The risks of ventricle laceration, coronary injury or pneumothorax have shown to decrease markedly using this technique [58].

Tension pneumothorax decompression is not, strictly speaking, a US-guided but rather an US-assisted procedure. In the course of a tension pneumothorax, the affected lung can be so overinflated to compress the controlateral lung and dislocate the mediastinum. This can alter markedly the normal lung sounds that could be heard from the ventilation of a healthy lung. US can be very useful in assessing the affected side. Although not burdened by serious complications in itself, pneumothorax decompression can have devastating effect if performed on the healthy lung. We thus believe that US scanning prior to puncture, seeking the well-known features of a ventilated lung [34], can increase the safety of the procedure.

Lastly, difficult IV access can be obtained by ultrasound guidance or assistance, exactly as routinely done in many ED. This technique is widely reported on many textbooks either of emergency US [30] or of emergency medicine procedures and has a sound scientific basis [59, 60]. The only other option in the prehospital arena is the placement of an intra-osseous access, which is surely quick and very effective, especially in small infants. To our knowledge, at present no study has ever compared the two techniques.

Conclusions

Several prehospital emergency medical services throughout the world have equipped some of their ambulances with ultrasound machines. Fewer others, following a more systematic approach, have or are planning to have all their medical vehicles supplied with ultrasound. Still, at present, ultrasound is not standard care in the prehospital arena. In EMS settings with higher-level providers (especially physicians), such as those that follow the FGM, ultrasound has a potentially wider role, greatly enhancing the physician's diagnostic and monitoring capabilities with a non-invasive, unharmful, repeatable, cost-effective tool. In an emergency system model that requires early diagnosis to take steps to optimize patient care and disposition, pre-hospital ultrasound constitutes a precious asset, yielding information otherwise unavailable. Although scant and in dire need of studies focused on clinical outcome, available literature indisputably supports the introduction of prehospital ultrasound scanning. As technical development is providing the physician with growingly small and performing devices, the issue of endowing medical-staffed ambulances with a portable ultrasound machine will soon be inescapable.

Conflict of interest None.

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