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Short paper

Management of persistent shockable rhythms during cardiac arrest: a national survey from the REVIVE group (REVIVE-2)

David B. Sidebottom[a,*], *Thomas Gleeson-Hammerton*[b,c], *John Pike*[b,i], *Adam J.R. Watson*[d], *Peter Owen*[e,f,g], *David Jeffery*[k], *Julian Hannah*[e,f,g], *Matthew Taylor*[h], *James Raitt*[i], *James Plumb*[e,f,g,j]

Abstract

Background: A number of novel treatment strategies have been proposed for managing persistent/refractory ventricular fibrillation (VF) and pulseless ventricular tachycardia (pVT). This survey investigated current practices amongst UK Helicopter Emergency Medical Services (HEMS) in preparation for a clinical trial of esmolol for persistent VF/pVT.

Method: This was a cross-sectional survey of the prehospital management of persistent VF/pVT by UK HEMS. A peer-reviewed, pre-piloted survey was distributed to all 21 UK HEMS in January 2025 via the National HEMS Research and Audit forum. The survey included the operationalised definitions of persistent VF/pVT and pharmacological/non-pharmacological management strategies used by services. The survey was distributed via Google Forms and analysed in R (v4.4).

Results: Of UK HEMS services that attend medical cardiac arrests, 19/20 (95%) responded. A formal protocol for the management of persistent VF/pVT existed in 10/19 (53%) services, with 8/10 (80%) defining persistent/refractory as $\geq$ 3 failed shocks. Modification of adrenaline dosing from the standard treatment algorithm was performed in 9/19 (47.4%) services (de-emphasised in all cases). Esmolol administration as part of a persistent VF/pVT protocol was reported by 2/19 (11%) of services. Most services administered intravenous lidocaine (14/19) and/or magnesium (18/19) for persistent rhythms or at the clinician's discretion. All services permitted vector change defibrillation technique for persistent VF/pVT, with 6/19 (32%) services additionally permitting dual sequential defibrillation.

Conclusion: Treatment strategies for managing persistent VF/pVT vary widely between UK HEMS. Further data is required to support an evidence-based pharmacological approach to this cohort.

Keywords: Refractory, Recurrent, Treatment-resistant, Persistent, Ventricular fibrillation, Pulseless ventricular tachycardia, Anti-arrhythmic, Adrenaline, Beta-blocker, Defibrillation, Out-of-hospital cardiac arrest

Background

Ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) which is not responsive to three or more attempts at defibrillation can be termed 'persistent'.[1] Persistent VF/pVT poses a clinical challenge, as survival decreases rapidly with each unsuccessful attempt at defibrillation.[2] Other terms relating to non-responsive rhythms, such as 'refractory' (a treatment fails to terminate the rhythm) and 'recurrent' (the rhythm is terminated but refibrillation occurs) VF/pVT are frequently used imprecisely, while the ability to clinically distinguish this difference with see-through cardiopulmonary resuscitation (CPR) electrocardiography is not yet widely available.[1] This paper will therefore use the term persistent to encompass both refractory and recurrent VF/pVT.

A wide range of management strategies have been proposed for persistent VF/pVT, including non-standard antiarrhythmics, increased defibrillation energy, alternative defibrillator pad

* Corresponding author at: Department of Anaesthesia and Intensive Care, Södertälje Hospital, Stockholm, Sweden.
E-mail address: david.sidebottom@regionstockholm.se (D.B. Sidebottom).

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placement, percutaneous stellate ganglion blockade, cardiac catheterisation during ongoing resuscitation, and extracorporeal membrane oxygenation (ECMO).[3–9] Attention has also been drawn to the potential negative effects of adrenaline during prolonged resuscitation attempts,[10] including increased myocardial oxygen consumption and arrhythmogenic effects, as well as the accumulation of adrenaline with repeated dosing according to current guidelines.[11] A 'de-emphasised' adrenaline dosing strategy and intravenous beta-blockers such as esmolol have been proposed as novel management strategies but currently lack high-quality evidence.[1,12, 13]

High-quality research is urgently needed to assist clinicians in selecting evidence-based treatment strategies in this patient group. As previously published in *Resuscitation Plus*, the REVIVE (Refractory VF InterVention with Esmolol) project aims to evaluate the use of esmolol in persistent VF/pVT.[1] However, the group has observed a wide variation in current clinical practice amongst prehospital services. This survey therefore aimed to map current practices amongst United Kingdom (UK) Helicopter Emergency Medical Services (HEMS) in preparation for a randomised trial of esmolol for persistent VF/pVT.

Method

Study design

This was a cross-sectional survey of the prehospital management of persistent VF/pVT by UK HEMS. The survey was distributed to all 21 UK HEMS in January 2025 via the National HEMS Research and Audit forum and was closed after four weeks. This project was defined as a service evaluation and therefore did not require formal ethical approval, but was pre-registered with the University Hospital Southampton internal quality improvement and service evaluation database (SEV/0773).

Setting

National HEMS research and audit forum

All UK HEMS participate in the National HEMS Research and Audit Forum voluntarily. The forum meets periodically and has previously coordinated various research and quality improvement projects across multiple services.

UK HEMS

UK HEMS are generally independent charitable organisations and cover the entire landmass of the UK. Organisations differ in structure, dispatch criteria, and type of clinician that is delivered to the scene of an incident, however a team comprising a doctor (usually an anaesthetic, intensive care medicine, emergency medicine and/or increasingly a dual-accredited prehospital medicine specialist) and specialised paramedic is standard. Prehospital emergency medicine (PHEM) is a distinct specialist training pathway accredited by the UK medical regulator. Services commonly provide a road-based service during non-flying conditions.

Data sources and variables. The peer-reviewed, pre-piloted survey was disseminated via Google Forms.[14] The survey included questions on the services' cardiac arrest protocols, the operationalised definitions of persistent VF/pVT, and a range of pharmacological and non-pharmacological management strategies. The survey also asked whether each treatment was performed within a protocol or at the clinician's discretion. The survey was completed by a senior clinician in each service (cardiac arrest, research, or medical lead) with knowledge of the explicit and implicit clinical norms and practices in their service.

Analysis. A descriptive analysis was performed in R (v4.4).[15] Data management and analysis were performed using standard packages including *tidyverse*.[16]

Results

Of the 21 UK HEMS, 20 responded to the survey. Of these, one HEMS declined to participate due to only attending trauma cases, leaving the responses of 19 services to be analysed. A formal protocol for the management of persistent VF/pVT existed in 10/19 (53%) services, with 8/10 (80%) defining persistent/refractory as after 3 failed shocks. One service defined persistent/refractory VF/pVT as after 5 failed shocks, while another service defined it as after 10 min of Advanced Life Support (ALS).

Pharmacological strategies

The number of HEMS providing each treatment is presented in Table 1. Table 2 presents each treatment stratified by whether administration was protocol-directed or provided at the clinician's discretion.

Modification of adrenaline dosing from the standard treatment algorithm was reported in 9/19 (47.4%) services (de-emphasised in all cases). One (5.3%) service reported the protocolised withholding of adrenaline in refractory VF/pVT, while 8/19 (42.1%) services reported a clinician-directed combination of withholding adrenaline, increasing the dosing interval, and titration against invasive measurement of blood pressure. The single service reporting the use of other vasoactive medication described the availability of noradrenaline and metaraminol for use at clinician discretion.

Esmolol administration as part of a persistent VF/pVT protocol was reported by 2/19 (11%) services, with one further service reporting the use of metoprolol at clinician discretion. Esmolol was provided with a bolus dose of 500 mcg/kg with or without a subsequent infusion at 50–100 mcg/kg/min.

Most (73.7%) services administered intravenous lidocaine, generally in addition to intravenous amiodarone. No service reported the standardised omission of amiodarone when providing lidocaine, although 4/14 (28.6%) services that administered lidocaine reported that amiodarone could be omitted at clinical discretion. Lidocaine was provided at doses ranging between 1 and 2 mg/kg. Almost all (94.7%) services provided magnesium for persistent VF/pVT or at the clinician's discretion. Magnesium was provided for various indications (all persistent VF/pVT, torsades de pointes, and/or coarse VF) at doses between 2 and 4 g. Intravenous bicarbonate 8.4% was provided at doses ranging from 1 to 2 ml/kg and as part of a protocol by 2 (10.5%) services for indications including presumed hyperkalaemia, prolonged cardiac arrest, and suspected toxidromes related to sodium channel blockade.

Defibrillation strategies

The number of HEMS providing each treatment is presented in Table 1. All services permitted vector change defibrillation technique (from anterolateral to anteroposterior electrode placement) for persistent VF/pVT, with 6/19 (32%) services additionally permitting dual sequential external defibrillation (DSED). One further service reported the planned implementation of DSED as part of a protocol.

Table 1 – Total number of HEMS providing each treatment, and number of HEMS with a written protocol for the management of refractory VT/pVT providing each treatment. HEMS = Helicopter Emergency Medical Service.

	All HEMS (*n* = 19)		HEMS with protocol (*n* = 9)	
Treatment	**Treatment provided (n)**	**%**	**Treatment provided (n)**	**%**
Pharmacological strategy				
Modification of adrenaline bolus	9	47.4	5	55.6
Adrenaline infusion	3	15.8	2	22.2
Other vasoactive agent	1	5.3	1	11.1
Esmolol	2	10.5	2	22.2
Other beta blocker	2	10.5	1	11.1
Lidocaine	14	73.7	8	88.9
Magnesium	18	94.7	8	88.9
Bicarbonate	8	42.1	4	44.4
Defibrillation strategy				
Modification of defibrillator pad position[1]	19	100	9	100
Modification of defibrillation time interval	2	10.5	0	0

[1] Vector change or Dual Sequential Defibrillation.

Table 2 – Number of HEMS providing each treatment, subdivided by whether treatment protocolised or provided at the discretion of the treating physician (whether as part of a written protocol or not).

Treatment	Clinician discretion	Protocol
Pharmacological strategy		
Modification of adrenaline bolus	8 (88.9%)	1 (11.1%)
Adrenaline infusion	3 (100%)	0 (0%)
Other vasoactive agent	1 (100%)	0 (0%)
Esmolol	0 (0%)	2 (100%)
Other beta blocker	2 (100%)	0 (0%)
Lidocaine	12 (85.7%)	2 (14.3%)
Magnesium	15 (88.3%)	3 (16.7%)
Bicarbonate	6 (75%)	2 (25%)
Defibrillation strategy		
Modification of defibrillator pad position[1]	10 (52.6%)	9 (47.4%)
Modification of defibrillation time interval	2 (100%)	0 (0%)

[1] Vector change or Dual Sequential Defibrillation.

Other strategies

No services provided manual pressure augmentation (where the operator presses on the defibrillator pads) during defibrillation attempts. Extracorporeal CPR (eCPR) was available in selected cases for 3/19 (15.8%) HEMS. However, eCPR was only initiated prehospitally in one service, while it was available after transport to the emergency department in two further services.

Discussion

This national survey of the management of persistent VF/pVT by HEMS, which achieved a near exhaustive response, demonstrated wide variability in managing cardiac arrest with persistent shockable rhythms. Most services provided intravenous lidocaine, magnesium, and vector change defibrillation while an inconsistent minority provided other strategies. Dosing strategies varied widely between services. Variations from ALS guidelines were almost entirely at the clinician's discretion. This highlights the previously unstudied but anecdotal experience of many UK HEMS clinicians, namely, that senior critical care teams routinely deviate from 'standard' ALS algorithms for cardiac arrest with specific characteristics. These findings underscore the continuing need for well-designed, adequately funded clinical trials to be undertaken in this area.

While some services limited the administration of magnesium to torsades de pointes, others provided magnesium for persistent VF/pVT more broadly, despite previous negative findings in randomised trials.[3,17,18] The widespread use of lidocaine was also notable, despite the lack of efficacy found in the ALPS trial for lidocaine in comparison to amiodarone or with placebo.[19] However, lidocaine is the only alternate pharmacological therapy with support in ALS guidelines and a Bayesian network *meta*-analysis has previously suggested its superiority in persistent ventricular arrhythmias.[20,21] This is caveated by the absence of a well-powered trial examining the combination of amiodarone and lidocaine, which was most commonly delivered by participating services in this survey.

Almost half of the services deemphasised adrenaline during persistent VF/pVT through modification of the dosing and/or timing from

ALS guidelines. Randomised trials have thus far been unable to demonstrate a clear advantage of adrenaline on patient-oriented outcomes for patients with shockable rhythms,[10,22] while sympathetic hyperactivity during cardiac arrest has long been associated with persistent or recurrent ventricular arrhythmias.[23] A supraphysiological plasma adrenaline concentration during cardiac arrest, both endogenous through a massive stress response and iatrogenic through repeated administration of adrenaline, may increase myocardial oxygen demand and may predispose patients to recurrent ventricular arrhythmias/fibrillation.[1] Furthermore, the half-life of adrenaline in plasma during cardiac arrest is prolonged, exacerbating its accumulation when administered according to ALS guidelines.[11] This hypothesis is supported by a recent analysis demonstrating that most cases of persistent VF are, in reality, recurrent rhythms with a short refibrillation interval,[24] while further observational work suggests that deemphasising adrenaline during persistent VF/pVT is associated with an improved rate of sustained ROSC.[13]

Four services provided beta-blockers during cardiac arrest, with two providing esmolol within a protocol for the management of persistent VF/pVT. The use of beta-blockers to blunt sympathetic hyperactivity during cardiac arrest has been an area of interest for over a quarter of a century.[23] Animal models have suggested that esmolol may reduce post-arrest myocardial dysfunction, improve cerebral perfusion pressure, and have a neuroprotective effect via a mechanism that is hitherto not entirely clear.[20,21] Retrospective cohort studies and case series have suggested an association between the use of esmolol/beta-blockers for persistent VF/pVT and the likelihood of (sustained) ROSC, as well as for patient-oriented outcomes.[12,13,25–28] However, no randomised or comparative trial has been performed to evaluate these early findings further.

A limitation of this study is that the authors did not audit the practices reported by participating services. The survey was recommended to be completed by a senior clinician in the service, or the cardiac arrest lead, who would normally have a deep knowledge of the clinical practices at the service as well as both explicit and implicit norms.

Conclusion

Treatment strategies for the management of persistent VF/pVT vary widely between UK HEMS. Further data is required to support an evidence-based pharmacological approach to this cohort.

CRediT authorship contribution statement

David B. Sidebottom: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Thomas Gleeson-Hammerton:** Writing – review & editing. **John Pike:** Writing – review & editing. **Adam J.R. Watson:** Writing – review & editing. **Peter Owen:** Writing – review & editing. **David Jeffery:** Writing – review & editing. **Julian Hannah:** Writing – review & editing. **Matthew Taylor:** Writing – review & editing. **James Raitt:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **James Plumb:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

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Author details

[a]*Department of Anaesthesia and Intensive Care, Södertälje Sjukhus, Stockholm, Sweden* [b]*Isle of Wight NHS Trust Ambulance Service, St Mary's Hospital, Isle of Wight, United Kingdom* [c]*University of South Australia, Adelaide, Australia* [d]*Royal Brisbane and Women's Hospital, Butterfield Street, Brisbane, Australia* [e]*Hampshire & Isle of Wight Air Ambulance, Nursling, Southampton, United Kingdom* [f]*Perioperative & Critical Care Theme, NIHR Southampton Biomedical Research Centre, Southampton, United Kingdom* [g]*University Hospital Southampton NHS Foundation Trust, Southampton, United Kingdom* [h]*Dorset and Somerset Air Ambulance, United Kingdom* [i]*Thames Valley Air Ambulance, Stokenchurch House, Stokenchurch, United Kingdom* [j]*Clinical & Experimental Sciences, Faculty of Medicine, University of Southampton, Southampton, United Kingdom* [k]*Patient and Public Involvement and Engagement Representative, United Kingdom*

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