

Mechanical ventilation of patients in helicopter emergency medical service transport: An international survey

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Abstract

Background: Mechanical ventilation in helicopter emergency medical service (HEMS) environments is a procedure which carries a significant risk of complications. Limited data on the quality and performance of mechanical ventilation in HEMS are available in the literature.

Method: We conducted an international survey to evaluate mechanical ventilation infrastructure in HEMS and collect data of transported ventilated patients. From June 20-22, 2019, the participating HEMS bases were asked to provide data via a web-based platform.

Results: Fifty-three HEMS bases responded. Respondents were from Germany, Denmark, United Kingdom, Luxembourg, Austria and Switzerland. Of the HEMS bases, all medical team leaders were physicians, mainly anesthesiologists (79%), the majority were board certified (92.5%) and trained in intensive care medicine (89%) and had a median (range) experience in HEMS of 9 (0-25) years. HEMS may provide a high level of expertise in mechanical ventilation whereas the majority of ventilators are able to provide pressure controlled ventilation and continuous positive airway pressure modes (77%). Data of 30 ventilated patients with a median (range) age of 54 (21-100) years and 53% male gender were analyzed.

Conclusion: In this pilot study, the management of ventilated HEMS-patients was not associated with ventilation related serious adverse events. Individual circumstances of patients, training of medical crew and different technical and environmental resources are likely to influence management. Further studies involving ventilated patients are necessary to assess safety and process quality of mechanical ventilation in HEMS.

Introduction

The management of ventilated patients in helicopter emergency medical service (HEMS) has the potential for severe and life-threatening complications that may worsen critical conditions (1, 2). These complications may include deterioration of the patients' condition due to dynamic character of the underlying diseases or injuries themselves, as well as iatrogenic complications caused by inappropriate ventilation, unsuitable level of anesthesia, inadequate muscle relaxation, and loss of intravenous lines, chest tubes, or monitoring (3). The need for mechanical ventilation per se is an indicator of the severity of diseases and injuries, and thorough monitoring through all steps of transportation is necessary to prevent complications (1, 2). Data on detailed process management of ventilated HEMS patients are scarce. Recent studies suggested that real-world handling of these high-risk patients may differ from desirable standards and often depends on the discretion of the attending HEMS team (4–6).

The aim of the present study was to assess the ventilator management in HEMS patients through an international survey.

Materials And Methods

The study was an online survey, without intervention and without data enabling to identify an individual HEMS team therefore (7). The requirement for ethical approval was waived following review by the Ethical commission of the Medical Faculty of Würzburg, Germany (ID: 20171024 01). The study complied with European data protection regulations and was prospectively registered on Research Registry (researchregistry2925). Participants were invited in a pan-European online announcement including three e-mail reminders. The E-mail-distribution list was obtained from national HEMS providers and supplemented by personal contacts of the authors. Participating HEMS teams were analyzed using an online questionnaire on three consecutive days June 20–22, 2019.

Statistic is mainly descriptive. Data are presented as number (%), mean (SD), or median (range) as appropriate. Mann Whitney U test was used to compare continuous or ordinal data of two independent groups. This non-parametric statistical method was used for comparing these groups because these method compare the ranks and not the crude numbers without the need for a normal distribution or equal variance of the data, and protect against small number of events. A p-value of less than 0.05 was considered significant and all computations were performed using GraphPad Prism 8 for Windows (GraphPad Software 2020, LLC).

Results

Two-hundred-fifteen HEMS bases were invited to take part in the study. Of these, 53 HEMS teams completed the study (25%), which were included in the analysis.

Characteristics of participants

Participating HEMS teams were from Germany (n = 26), Denmark (n = 16), United Kingdom (n = 6), Luxemburg (n = 2), Austria (n = 2) and Switzerland (n = 1). HEMS availability was quoted 51% 24-hours and 45% until sunset (4% no response). Helicopter types were quoted Airbus H135 and predecessors 55%, Airbus H145 and predecessors 26%, McDonnell Douglas (MD) 902 13%, and Agusta Westland DaVinci 2% and 4% other types. Pilot configuration was quoted 70% single pilot, 13% dual pilot, and 17% dual pilot depending on time of day. A median (range) of 4 (0–8) HEMS mission per day were performed during the study period by the participating HEMS teams.

Medical crew qualification

Medical team configuration was physician staffed in all respondents (physician/paramedic 92.5% and physician/flight nurse 7.5%). Three respondents (10%) had an additional trainee or resident physician on board. Most physicians had a median (range) experience in HEMS of 9 (0–25) years, were anesthesiologists (79%), board certified (92%), and had a special ICU training (89%).

Ventilator equipment

Helicopter ventilators were able to provide only volume-controlled ventilation (VCV) in 23% of the services whereas 77% could provide pressure control ventilation (PCV) and continuous positive airway pressure

(CPAP) ventilation. The most common used ventilator in the VCV only group was the Oxylog 2000 (Dräger Lübeck, Germany) and in the PCV group the Oxylog 3000 series (Dräger Lübeck, Germany). Bag/mask ventilation (BMV) was quoted as ventilator backup in all cases (55% including O₂-demand option) while six respondents (11%) reported carrying an additional ventilator on board. Two teams perform blood gas analysis on board. A roll-in stretcher was available on 34% of the aircrafts.

Patients' characteristics

A total of 30 ventilated patients with a median (range) age of 54 (21–100) years were transported. Sixteen patients (53%) were male. Eighty percent (n = 24) of the included patients were from primary missions while six patients underwent interfacility transport (five patients from intensive care unit, ICU, and one patient from emergency department, ED). Fifteen patients (50%) suffered from trauma, seven (23%) from cardiac arrest of whom four already had a return of spontaneous circulation (ROSC) following out-of-hospital cardiopulmonary resuscitation (CPR), while one underwent helicopter transport with ongoing mechanical chest compressions using an automatic chest compression device (ACCD).

Other diagnoses of patients were neurologic/neurosurgical (n = 6), acute respiratory distress syndrome (ARDS, n = 2), and burns (n = 1). Airway management was performed by the HEMS-team in 18 cases (60%) of which all patients underwent tracheal intubation except one patient with a supraglottic airway device (laryngeal tube). Mechanical ventilation was performed using volume-controlled ventilation in 17 (59%) and pressure-controlled ventilation in 12 (41%) patients with a median (range) tidal volume of 6 (4–7) mml/kg body weight.

Data upon vital functions and ventilator settings at first patient contact and at handover are provided in *Table 1*. Two patients (7%) deteriorated during flight due to underlying critical conditions as reported by the respondents. 97% of all patients had capnography monitoring (etCO₂) during transport. Pulse-oximetry (SpO₂) was measurable in 27 patients (90%) while in the remaining three cases, patients were in a state of circulatory shock without sufficient peripheral perfusion for SpO₂ measurement. At the hospital helipad, a hospital ventilator was provided in nine cases (31%), oxygen was provided in 20 cases (69%), and a medical receiving team was provided in another 20 cases (69%). Ventilation during transfer from the helipad to the receiving department was performed using the helicopter ventilator in 25 patients (83%), using a hospital ventilator in three patients (10%) and using manual bag-ventilation in one patient (3%). During transfer to the receiving department, the HEMS team carried an emergency bag / backpack in 21 cases (72%), a BMV in 27 cases (93%) and ACCD in two cases (ACCD being active in one case, as described earlier). Handover was carried out in the ED in 19 patients (65%), in the ICU in six patients (21%) and in the percutaneous coronary intervention (PCI) suite in four patients (14%).

Patients' devices and catheters included IV-lines in all but one patient (97%) who had intraosseous access. A single IV line was present in five (17%) patients, two IV-lines in 22 (73%) patients, and three IV-lines in one (3%) patient. A central venous catheter (CVC) was present in seven patients (23%) (n = 2 in the internal jugular vein, n = 1 in the subclavian vein, n = 4 in the femoral vein). Invasive arterial blood

pressure measurement was carried out in five patients (n = 4 of the arterial lines were in the radial artery, n = 1 in the femoral artery). A urinary catheter was present in six patients (20%). All the mentioned catheters (central venous, arterial, urinary) were present in patients during interfacility transport.

Furthermore, an abdominal drain, bilateral chest tube and pelvic sling were present in one patient, each. Syringe pump devices for continuous drug administration were present in 14 patients (48%) of which one syringe pump was used in 10 patients, two and three syringe pumps in two patients, each, and four syringe pumps in one patient. Most frequent drug administration during flight was quoted analgesics (93%), neuromuscular blocking agents (45%), and vasopressors (43%).

Discussion

Mechanical ventilation in HEMS is a frequently performed procedure although there may be different rates across different health care systems. Almost 20% of the HEMS missions in our study involved the transport of mechanically ventilated patients. Approximately half of all mechanically ventilated HEMS patients were interfacility transports of critical care patients (8).

In general, there are only few studies on the process quality of mechanical ventilation in HEMS environments (4, 5, 9, 10). Key results of our small study sample demonstrate that participating HEMS-teams were entirely physician-staffed and provided a high expertise in critical care management and long experience in HEMS. Included patients had no transport-related complications of airway management and ventilator use.

In the literature, critical events (i.e., inadvertent extubation, loss of IV-lines, cardiopulmonary deterioration) occur in approximately 5% of HEMS transports of patients who are critically ill, rising up to 18% when focusing on systems with paramedics as the sole health care provider conducting interfacility critical care transfers. (11). Nevertheless, fatal events during HEMS transport are reported in less than 0.2% of cases (1, 9, 12).

Regarding ventilator settings, all patients of the present study were ventilated with low tidal volumes and almost every second patient underwent pressure controlled ventilation (PCV), and even though the evidence of low tidal volume ventilation or PCV in patients without ARDS is low the HEMS teams use ICU standards of ventilation during transport (13, 14). This is in contrast to published literature where tidal volumes have been reported to be above 6 ml/kg body weight in 86% of patients and most patients receive volume control ventilation during transport (6). This may be explained by the low pre-hospital availability of transport-ventilators with PCV-mode in older studies. Nowadays modern transport-ventilators with PCV-mode are widespread even in the pre-hospital setting. High FiO₂ during HEMS transport are common and may be the result of safety measures to prevent critical desaturation and of rare ability to perform blood gas analyzes during transport (9).

End-tidal capnography monitoring has an essential value of safety during HEMS transport. First, tube dislodgement may be detected reliably, second, hypocapnia or hypercapnia can be adjusted by changing

mechanical ventilation parameters, and third, it provides prognostic value in highly critical patients (15–18). Hypocapnia secondary to hyperventilation is a frequent iatrogenic complication during pre-hospital ventilation (19). This has been most commonly documented among patients with traumatic brain injury and occurred in up to 79% of patients (19, 20). Pre-hospital hyperventilation and the resulting hypocapnia are associated with poor outcomes, including increased mortality rates due to cerebral vasoconstriction causing cerebral ischemia (21). The use of pre-hospital capnography monitoring has been identified as an outcome relevant quality parameter in the German trauma registry (TraumaRegister DGU) (22). The high percentage (>95%) use of capnography in our study demonstrate the perception of the mentioned problems by the HEMS-teams.

Despite the risk of ventilator-associated critical events during HEMS-transport, there may also be opposite effects in terms of improvement of ventilation and respiratory function. In our small study, PEEP-levels were significantly higher after transportation compared with pre-transportation PEEP, but the clinical relevance of these higher PEEP-levels could not be assessed. For instance, If the change in PEEP-level caused a PEEP over the lower inflection point of the lung, this change could be clinically relevant (23).

Across multiple studies, critical care transport teams with training in complex ventilator management are associated with improved PaO₂ after transfer (9, 10, 12). The transporting team changed ventilator settings during transport in most patients (decreasing tidal volume, increasing PEEP, and increasing FiO₂). Furthermore, the use of neuromuscular blocking drugs is a common measure to improve respiratory function under mechanical ventilation in HEMS (9, 10). Our data confirm these findings (45% of patients) although there was a high proportion of on-scene rescue missions and rapid sequence intubation in our cohort compared with other studies.

Notably, mechanical ventilation parameters provided by HEMS teams are known to considerably influence initial hospital ventilation parameters after patient handover (6). Besides focusing on ventilated patients, our study-sample demonstrated a high level of expertise of participating HEMS-teams across Europe. In all cases the HEMS-teams were physician-staffed with many years of HEMS-experience along with a high proportion of board certification and ICU-training. No other studies have reported this kind of data.

Limitations

In this pilot study, we included a small number of HEMS-teams and patients undergoing mechanical ventilation during flight. Unfortunately the number of responding HEMS-bases was relatively low compared to the more than 200 bases invited. Furthermore, the study sample represents a heterogeneous proportion of patients of on-scene emergency responses and interfacility transports. Therefore, the management goals of these patients may not be representative of the larger patient population. Participating HEMS-teams were physician-led and other team configurations (e.g. flight nurse/paramedic or paramedic/paramedic) may have had different performances (24–27). More than half of the participating HEMS-teams were German speaking countries. Therefore, our results may not be applicable

to the general HEMS-population. However, we provide first data on the real-world management of mechanically ventilated HEMS-patients and our results may indicate topics relevant for future studies.

Conclusions

In this pilot study, the management of ventilated HEMS-patients was not associated with ventilation related serious adverse events. Individual circumstances of patients, training of medical crew and different technical and environmental resources are likely to influence management. Further studies involving larger sample sizes are necessary to clarify whether different management strategies may influence patient safety and improve process quality of mechanical ventilation in HEMS.

Declarations

Ethics approval and consent to participate

The requirement for ethical approval was waived following review by the Ethical commission of the Medical Faculty of Würzburg, Germany (ID: 20171024 01).

Consent for publication

Not applicable

Availability of data and materials

The survey data used to support the findings of this study are available from the corresponding author upon request.

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Authors' contributions

P. H-C. & M. F. St. designed the survey and wrote the first manuscript draft, J. H. / Th. W. / M. B. / B. H. were involved in improving the questionnaire of the survey and the manuscript, J. H. & V. H. did the statistical analysis and helped with the manuscript, L. R. & J. A. helped with data collection and manuscript improvement, M. D. Ch. helped with the manuscript and the English editing. All authors read and approved the finale manuscript.

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Table

Table 1) Vital signs and ventilation settings at first patient contact and at handover.

		Values at first contact	Values at handover	p-value
HR [1/min]	median (range)	97 (0-220)	96 (0-174)	0.51
	mean±SD	99±53.7	95±32.7	
SBP [mmHg]	median (range)	159 (130-189)	120 (90-175)	0.14
	mean±SD	159±41.7	124±22.5	
RR [1/min]	median (range)	14 (0-22)	14 (0-20)	0.5
	mean±SD	13.3±5	14.5±1.9	
SpO ₂ [%]	median (range)	95 (0-100)	99 (0-100)	<0.001*
	mean±SD	80.3±25	94.7±18.7	
EtCO ₂ [mmHg]	median (range)	36 (0-60)	36 (19-67)	0.68
	mean±SD	34.5±13.5	37.6±9.5	
PEEP [cmH ₂ O]	median (range)	5 (0-8)	5 (0-10)	0.04*
	mean±SD	4.4±2.6	5.9±1.8	
PiP [cmH ₂ O]	median (range)	22 (0-40)	22 (16-45)	0.68
	mean±SD	23±8	22.5±5.7	
TV [ml]	median (range)	500 (350-600)	500 (360-700)	0.55
	mean±SD	495±65.6	495±74.6	
TV/BW [ml/kg]	median (range)	6 (4-7)	6 (4-7)	0.5
	mean±SD	5.7±1.6	6±0.98	

*results statistically significant

HR - heart rate, SBP - systolic blood pressure, RR - respiratory rate, SpO₂ - oxygen saturation, EtCO₂ - expiratory CO₂, PEEP - positive end-expiratory pressure, PiP - positive inspiratory pressure, TV - tidal volume, BW - body weight

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