Heliyon 10 (2024) e40688

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Changes in the helicopter medical service system of L'Aquila (Italy), after the fatal helicopter crash on Monte Cefalone (January 24, 2017). A retrospective study

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A B S T R A C T

Introduction: The use of helicopter emergency medical services is useful for rescuing or transporting highly time-dependent disease patients, from urban remote areas or harsh environments in the hospital, providing advanced pre-hospital life support in an emergency setting.
Study objective: This study aims to identify changes in mission characteristics, crew composition, and operational procedures within the helicopter emergency medical service (HEMS) system of L'Aquila, Italy, to identify operational patterns, mission characteristics, crew composition and patient outcomes over time, with specific attention to changes implemented after the Monte Cefalone incident.
Methods: Changes in the characteristics of the rescued patients, the helicopter missions, the crew members and the type of interventions were analysed. T-test or chi-square test were used to compare data before and after the incident.
Results: Three thousand three hundred and ninety-two records were reviewed. Following the crash, a pilot was added to the crew. Two hundred and thirteen missions were classified as cancelled: 47 before and 166 after the crash. The cancellations due to the lack of horizontal visibility were: 4 out of 47 (8.5 %) and 24 out of 166 (14.5). Most of the rescued victims had trauma: 45 % before and 50 % after the crash. The helicopter flights were prevalent in harsh environments. After the accident, the percentage of missions in harsh environment decreased from 80 % to 64 %. The type of rescue and operations changed significantly ($p < 0.001$). The proportion of hospitalized patients increased from 60 % to 93 % while the recorded deaths in place were similar (6 % vs 7 %). A decrease in the number of transport refusals, from 4 % to 0.4 %, was reported.
Conclusion: The results of our research highlighted that the helicopter emergency medical service of L'Aquila continued to fly in safety, for patient rescue and hospitalization despite being subjected to harsh conditions and environments, and despite the accident.

1. Introduction

The use of helicopter emergency medical services (HEMS) and hospital admission are both free of charge in Italy. The HEMS system is useful for rescuing or transporting highly time-dependent disease patients, from urban remote areas or a very hard to survive environment (harsh environment) [1] in the hospital, providing advanced pre-hospital life support in an emergency setting [2–4]. The National Health Service in Italy is decentralised at the regional level, and each region is organized by local health authorities. The HEMS is managed and activated by local Emergency Department Dispatch Centre (EDDC).

The HEMS crew includes an anaesthetist, a nurse, 1 or 2 pilots, a mountain guide, and a hoistman. The EDDC requests activating the HEMS, to provide both emergency cover in the catchment area (primary rescue) and interhospital patient transfer (secondary rescue)

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https://doi.org/10.1016/j.heliyon.2024.e40688
Received 19 August 2024; Received in revised form 21 November 2024; Accepted 23 November 2024
Available online 26 November 2024

Abbreviations

HEMS	helicopter emergency medical service
EDDC	Emergency Department Dispatch Centres
GEMS	ground emergency medical service
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
EQUATOR	Enhancing the QUAlity and Transparency Of health Research
SAR	Search And Rescue
STAMP	Systems Theoretic Accident Model and Process
ENAC	Civil Aviation Authority
EASA	European Union Aviation Safety Agency

[5,6].

In the Abruzzo region (Central Italy), there are two HEMS crews: one is in the mountain area close to the city of L'Aquila (West side), and the other one is in the coastal area, near the city of Pescara (East side). In L'Aquila the HEMS is only a daytime service, because it is not equipped with Night Vision Goggles (NVG) or other devices for night flight. Before February 2017, a single pilot is in the HEMS crew.

On January 24, 2017, a man who fell at 1600 m above sea level in the Campo Felice ski area reported tibia and fibula fractures. The HEMS crew of L'Aquila was immediately activated and rescued the skier. After a few minutes from helicopter's departure, the helicopter vanished in the fog and crashed on Monte Cefalone, near the ski area of Campo Felice. There were no survivors from the crash [7]. In 25 years of HEMS activity in L'Aquila, this is the first fatal accident.

Several studies have investigated the psychological and behavioral responses of populations to aviation accidents [8]. The availability heuristic, where individuals estimate the probability of events based on their ability to recall similar incidents, plays a significant role in shaping public perception. After a HEMS crash, the heightened awareness of the risks involved can lead to increased fear and reluctance to use such services [9].

Intensive social media usage and the relative discussions about aviation accidents can significantly contribute to vicarious traumatization [10], amplifying public fear toward air medical transport [11].

We hypothesized that the helicopter crash could have affected the HEMS system's activities in L'Aquila. We supposed that the incident in mountainous areas may have unsettled the public, prompting them to take greater precautions before engaging in activities in these areas, thereby reducing the number of accidents and subsequent emergency interventions. Furthermore, the HEMS feared that the crash may have discouraged flying and prevented helicopter transportation or may have influenced the distribution of mission cancellations.

Thus, we aimed to explore changes in mission characteristics, crew composition, and operational procedures within the Helicopter Emergency Medical Service (HEMS) system of L'Aquila, Italy. Our goal was to identify operational patterns, mission characteristics, crew composition, and patient outcomes over time, with particular attention to the changes implemented after the Monte Cefalone incident.

2. Material and methods

This is a retrospective study of rescued patients' characteristics and outcomes of helicopter missions, as well as HEMS crew composition, by analysing the data from the medical reports from January 1, 2012, to December 31, 2022.

Data Collection.

The dataset is focused on structural aspects, such as mission cancellations, crew composition, and patient outcomes. We did not directly approach to sensitive data of rescued patients and our data do not include psychological or individual-level assessments but instead focus on structural adjustments and mission parameters.

They were pre-existing administrative health care data; subjects could not be directly or indirectly identified. All data was fully anonymized, and the study was authorized by the Emergency Department Manager of our Local Health Authority. The applicable Enhancing the Quality and Transparency of Health Research (EQUATOR) guidelines for observational studies (Strengthening the Reporting of Observational Studies in Epidemiology, STROBE) were respected.

Organizational Factors.

The HEMS crew of L'Aquila worked with the Bell 412 helicopter from January 2012 to July 2015. In July 2015, the Augusta Westland 139 (AW139) replaced it. During maintenance, the BK 117 C-2 is sometimes used as a substitute for the AW 139.

L'Aquila is surrounded by four mountain ranges: the Gran Sasso d'Italia (2,912m, above sea level asl) and the Laga mountains, the Velino-Sirente mountain (2,487m asl), and the Majella massif (2,793 m asl).

The EDDC dispatcher receives the information about the emergency, and he can decide to assign the mission to the HEMS crew when the call of rescue comes from urban remote areas, harsh environments, or when ground emergency medical services (GEMS) cannot arrive. The Emergency Department Dispatch Center (EDDC) decisively assigns missions to the HEMS crew, ensuring that all mission decisions are made externally.

The mission rescue requested may be cancelled by the EDDC dispatcher if there are mechanical problems with the helicopter or

other reasons, such as ground emergency medical service teams reaching and rescuing victims. If the pilot lacks horizontal visibility before or during the flight, he can decline the rescue mission, and it results as cancelled [12].

Operational factors.

The types of rescues considered in this context are categorized as follows: "primary" rescues occur when interventions are conducted directly at the patient's home or at the scene of the event, whether in urban or non-urban areas; "secondary" rescues involve transporting patients between different hospitals, either within or outside the Abruzzo region; and "search and rescue (SAR)" operations are initiated when it is necessary to locate and rescue individuals in challenging environments.

The challenging environments in which the HEMS crew operates include areas where survival is difficult due to extreme temperatures, limited accessibility, low oxygen levels in the atmosphere, and other conditions that make it hard for humans to endure. In the Abruzzo region, activities such as ski mountaineering, hiking, climbing, canyoning, caving, and mountain biking are common in mountain ranges, where extreme environmental conditions prevail.

The report from the accident was in custody by the Italian Judiciary, and it was not considered in the study.

Any records that were unclear or incomplete were not included in the research.

The following data were analysed:

Organizational factors.

a) Number of HEMS rescue missions over time and per year.
b) Reasons to cancel HEMS mission: "dispatch from EDDC", "horizontal visibility less than 1500 m", "helicopter mechanical problems", and "others" (ground emergency medical service teams reaching, rescuing, and hospitalizing victims).
c) Functions of the HEMS crew.

Operational factors.

a) Environment: "urban remote areas" or "harsh environment".
b) HEMS' operation: "landing", "hovering exits off," "hoisting and lifting procedure", "hovering exits off and hoisting".
c) Type of rescue: "primary", "secondary", and "SAR".

Patient and Mission Characteristics.

a) Age, and sex of patients.
b) Presumable disease: "trauma" [13], "acute neurological disease", "acute cardiovascular disease" or "other".
c) Patient outcome: "alive at the time of hospitalization", "death on-site", "refusal by the patient/victim to rescue and transport".
d) Hospitalization: "No", "inside or outside the Abruzzo region".

2.1. Theory and calculation

All variables were analysed and reported as a proportion or mean with standard deviation (SD). Categorical data were compared using the chi-square test or Fisher's exact test. To compare numerical measurements before and after the accident, a *t*-test was conducted. STATA MP/14 software was used to carry out all analyses, which were set to alpha 0.05.

3. Results

From January 1, 2012, to December 31, 2022, a total of 3,392 missions were evaluated.

We were able to analyse 3,176 records in the available data set, while 216 records were excluded: n. 3 because of missing data and a total of 213 rescue missions was cancelled.

Following the helicopter accident, the HEMS team retained the same members but with 2 pilots instead of 1.

Table 1 summarizes the reasons for the cancelled missions, which were excluded from the study.

Fig. 1 summarizes the frequency (number) of rescue missions from January 1, 2012, to December 31, 2022.

Table 2 shows the characteristics of the rescued victims. There were no significant differences in the age and gender distributions of rescued victims before or after the accident ($p > 0.05$), as shown in Table 2. The distribution of the presumed causes of diseases was

Table 1
Reasons for the cancelled missions.

	All N = 213	Before Incident N = 47	After incident N = 166
Reason	N (%)	N (%)	N (%)
Emergency Department Dispatch Centre dispatcher's decision	133 (62.4)	35 (74.5)	98 (59.0)
Lack of horizontal visibility	28 (13.1)	4 (8.5)	24 (14.5)
Helicopter mechanical problems	5 (2.4)	2 (4.2)	3 (1.8)
Other	47 (22.1)	6 (12.8)	41 (24.7)

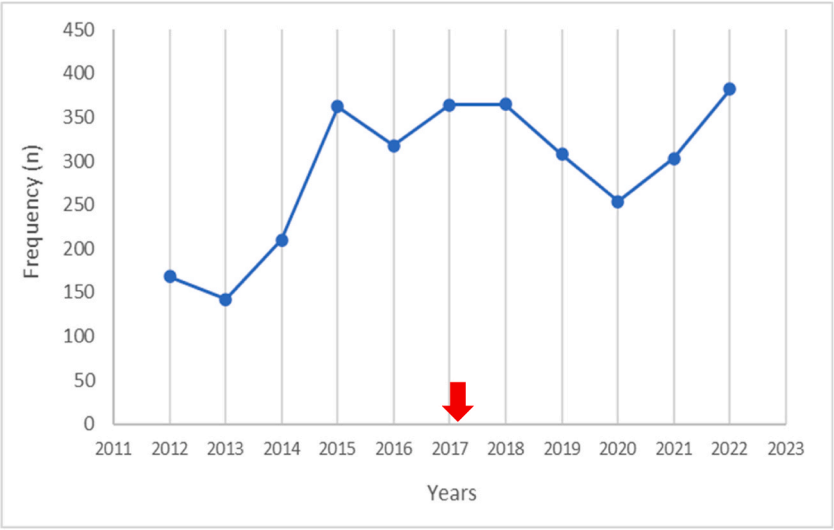

Fig. 1. Frequency (number) of rescue missions from January 1, 2012, to December 31, 2022.
The red arrow shows when the helicopter crashed. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

significantly different before and after the accident, evidencing an increase in trauma [8] from 45 % to 50 % and acute neurological disease from 12 % to 16 % ($p < 0.001$).

The two investigated periods had a similar proportion of deaths that occurred on the spot in terms of patient outcomes (6 % vs 6.9). The proportion of patients who refused the transport was lower after the accident (0.4 %) if compared to the time before the accident (4 %).

During the 11 years, a total of 2,618 patients were hospitalized in the Abruzzo region, 193 were hospitalized outside the region, and 365 did not need hospitalization. After the helicopter crash, most of the hospitalizations were in the Abruzzo Region. The distribution of the place of hospitalization was statistically different ($p < 0.001$).

As reported in Table 3, in 70 % of the HEMS missions (2,237), crew members operated in harsh environments. In only 30 % of the cases, the crew was employed in remote urban areas. The distribution of environments differed significantly between the two periods ($p < 0.001$). After the accident, the ratio of missions in harsh environments was lower (80 % vs 64 %).

The type of rescue distribution was different before and after the incident ($p < 0.001$): the secondary interventions were 250 before the accident and 468 after the accident, the number of SAR missions increased from 7 to 56. In 86 % of the missions, the helicopter made it to the target without any issues, but in 3 % of the missions, it was necessary to perform hoisting and lifting procedures. In 10 %

Table 2
Characteristics of the rescued victims.

	All N (%)	Helicopter accident		p-value[b]
		Before N (%)	After N (%)	before vs after
Sex (n = 3079)[a]				
Female	965 (31 %)	380 (39 %)	585 (32 %)	0.755
Male	2114 (69 %)	845 (69 %)	1269 (68 %)	
Age mean (SD) (n = 3079)[a]	53 (22.4)	53 (22.6)	52 (22.3)	0.156
Presumable disease/mechanism of injury (n = 3156)				
Trauma	1517 (48 %)	554 (45 %)	963 (50 %)	<0.001
Acute neurological disease	441 (14 %)	141 (12 %)	300 (16 %)	
Acute cardiovascular disease	650 (21 %)	256 (21 %)	394 (20 %)	
Other	548 (17 %)	272 (22 %)	276 (14 %)	
Patients' outcome				
Alive at the time of hospitalization	2917 (92 %)	1109 (90 %)	1808 (92.7 %)	<0.001
Death on place	192 (6 %)	71 (6 %)	135 (6.9 %)	
Refusal to rescue and transport	53 (2 %)	45 (4 %)	8 (0.4 %)	
Hospitalization				
No	365 (11 %)	222 (18 %)	143 (7 %)	<0.001
In Abruzzo region	2618 (83 %)	918 (75 %)	1700 (87 %)	
Outside the Abruzzo region	193 (6 %)	85 (7 %)	108 (6 %)	

[a] Totals are not 3176 because of missing data.
[b] Chi-square test or t Student test.

Table 3
Helicopter emergency medical system characteristics before and after the accident.

	All N (%) = 3176	Before accident N (%) = 1225	After accident N (%) = 1951	p-value[b]
Environment				
Remote urban areas	939 (30 %)	246 (20 %)	693 (36 %)	<0.001
Harsh environment	2237 (70 %)	979 (80 %)	1258 (64 %)	
Type of rescue				
Primary	2395 (75 %)	968 (79 %)	1427 (73.1 %)	<0.001
Secondary	718 (23 %)	250 (20.4 %)	468 (24 %)	
Search and Rescue [SAR]	63 (2 %)	7 (0.6 %)	56 (2.9 %)	
Type of operation (n = 3154)[a]				
Landing	2715 (86 %)	1,149 (93.8 %)	1,566 (81 %)	<0.001
Hovering exits off	320 (10 %)	62 (5 %)	258 (13 %)	
Hoisting and lifting procedures	80 (3 %)	7 (0.6 %)	73 (14 %)	
Hovering exits off and hoisting	39 (1 %)	7 (0.6 %)	32 (2 %)	

[a] Totals are not 3176 because of missing data.
[b] Chi-square test.

of the missions, HEMS crew members disembarked via hovering exits off, while in 1 % of cases, hovering exits off combined with hoisting and lifting procedures were used. The distribution of HEMS operations differed in the two periods ($p < 0.001$) with a decrease in landing operations and an increase in all other operations. According to Table 4, stratifying by environment mission we didn't find any differences by sex or age before and after the incident. The distribution of patient characteristics showed significant variations in a harsh environment, indicating that trauma decreased in harsh environments and increased in remote rural areas.

Table 4
Patient characteristics according to the environment mission, before and after the incident.

Remote Urban Area			
	Before Incident	After Incident	p
Sex	N (%)	N (%)	
Female	71 (28.9 %)	200 (30 %)	0.742
Male	175 (71.1 %)	467 (70 %)	
Age mean (SD)	54.5 (21.35)	52.2 (22.55)	0.159
Disease			
Trauma	171 (69.8 %)	486 (72.0 %)	0.113
Acute neurological disease	10 (4.1 %)	42 (6.2 %)	
Acute cardiovascular disease	21 (8.6 %)	66 (9.8 %)	
Other	43 (17.6 %)	81 (12.0 %)	
Patients' outcome			
Alive at the time of hospitalization	210 (85.4 %)	627 (91.9 %)	<0.001
Death on place	23 (9.3 %)	51 (7.5 %)	
Refusal to rescue and transport	13 (5.3 %)	4 (0.6 %)	
Hospitalization			
No	62 (25.2 %)	70 (10.1 %)	<0.001
In Abruzzo region	181 (73.6 %)	621 (89.6 %)	
Outside the Abruzzo region	3 (1.2 %)	2 (0.3 %)	
Harsh Environment			
	Before Incident	After Incident	p
Sex	N (%)	N (%)	
Female	309 (31.6 %)	385 (32.4 %)	0.665
Male	670 (68.4 %)	802 (67.6 %)	
Age mean (SD)	53.3 (23. 0)	52.5 (22.2)	0.410
Disease			
Trauma	383 (39.2 %)	477 (37.9 %)	<0.001
Acute neurological disease	131 (13.4 %)	258 (20.5 %)	
Acute cardiovascular disease	235 (24.0 %)	328 (26.1 %)	
Other	229 (23.4 %)	195 (15.5 %)	
Patients' outcome			
Alive at the time of hospitalization	899 (91.8 %)	1,181 (94.1 %)	<0.001
Death on place	48 (4.9 %)	70 (5.6 %)	
Refusal to rescue and transport	32 (3.3 %)	4 (0.3 %)	
Hospitalization			
No	160 (16.3 %)	73 (5.8 %)	<0.001
In Abruzzo region	737 (75.3 %)	1,079 (85.8 %)	

4. Discussion

The study analysed missions performed from 2012 to 2022, to identify the characteristics of rescue missions and the health problems which were the most common cause of intervention in the area, considering the date of the incident as a reference point.

This research indicated that the number of HEMS flights increased over time during the observation period. The number of flights decreased between 2019 and 2020, but then it started to increase again from 2021 to 2022. The observed reduction in mission frequency during 2019–2020 likely correlates with the COVID-19 pandemic, as restrictions and reduced public outdoor activities may have temporarily lowered emergency needs, affecting HEMS dispatch frequency during this period. We believe that this fluctuation may be due to the impact of the COVID-19 pandemic on medical emergency services [14].

The first change reported was that, following the helicopter accident, the HEMS team retained the same members but with 2 pilots instead of 1.

The study evidenced that a total of 213 missions was declined by pilots: 47 were recorded before and 166 after the incident. An important finding was that the cancellations of missions due to the lack of the requested horizontal visibility were 4 before and 24 after the crash. It is possible to speculate that the main reason to decline the mission is the lack of horizontal visibility, maybe related to the climate change in the Abruzzo region [15]. Thus, the two pilots could probably explain greater prudence and attention to visibility, avoiding to put the helicopter flight at risk, as recommended by the Italian Civil Aviation Authority [12] and as reported by Ramée [16].

Concerning the patient's characteristics, our findings showed that trauma and cardiovascular diseases [17,18] were the most common diagnoses that led to HEMS interventions. These results are consistent with previous studies [19–21]. The HEMS crew members of L'Aquila primarily operated in harsh environments (70 % of missions). When comparing the two periods, there was a difference in the distribution of missions between urban remote areas and harsh environments ($p < 0.001$), and stratifying by environment mission the study evidenced that trauma decreased in harsh environment and increased in urban areas. The decrease in rescue in harsh environments could be explained by a shift in the nature or location of the incidents, despite an increase in trauma patient interventions. Additionally, we speculate that the knowledge of the incident may have influenced people of L'Aquila to take greater precautions before engaging in sports activities in harsh environments [22].

The types of rescues and the HEMS operations changed between the two periods, indicating a decrement in primary rescue (79 %–73 %), and an increase in SAR missions: 7 (0.6 %) vs 56 (2.9 %) that relate to missions carried out in with greater complexity [23]. The SAR missions justify the HEMS activation [24] and operations. This data could justify that the number of landing operations decreased after the incident, while the number of other operations (such as hovering, hoisting, and lifting) increased. According to Pieysch et al., a helicopter hoist operation is a rescue technique used by HEMS in mountain areas to extricate patients [25].

The patient outcomes were comparable between the two periods, even though there was a higher number of hospitalized patients in the Abruzzo region after the incident.

The organizational models to reveal HEMS organizational vulnerabilities and degradation phenomena that generate flaws in the control processes after a fatal accident, are focused to identify shortfalls in the actions of practitioners and in the capacities of organizations to bring about a safe system. The AcciMap technique, that guide analysts to look beyond the immediate events involving individual operators and examine management factors that created the pre-conditions for accidents, and Systems Theoretic Accident Model and Process (STAMP) technique that focuses on the control processes and constraints between different levels in the safety management system, are two accident investigation techniques which have been developed in identifying flaws of control processes and problems in enforcing constraints between different levels in the organization [26]. However, controversy remains in adapting the theoretical organization models to the individual capacity to make the appropriate decision for the environment conditions and weather or change the environment to suit themselves.

Of the many publications that examine HEMS crashes and organization safety models, most identify the reason for a skill-based error may be due to fatigue, overconfidence, or recklessness [27]. A failure in critical thinking, and in the decision-making process (e.g., not considering weather conditions and the clearance of the horizontal visibility) can force HEMS crewmembers to use inappropriate procedures or operate with a rush, leading to fatal accidents [27]. The recommendations from the Italian Civil Aviation Authority (ENAC) in accordance with the European Union Aviation Safety Agency (EASA) regulations underline that pilots are forbidden to consecutively fly over 8 h, the visibility must be higher than 1500 m, and the double pilot can be requested for HEMS flight and operations, in remote urban areas and in regions with harsh environments [28].

A relevant observation in our study was that contrary to our hypothesis, the number of transport refusals decreased from 4 % to 0.4 %. It's possible that this finding is a consequence of the constant reinforcement of safety protocols, as well as the addition of more pilots. The improvements of safety protocol could have influenced to restore trust in HEMS operations. Previous studies indicated that positive perceptions of teamwork and communication were significantly associated with higher overall perceptions of patient safety [29].

5. Limitations

The study presents limitations. The generalizability of the findings may be limited by the fact that the data was collected exclusively from L'Aquila HEMS, so it was not possible to compare data with other HEMS systems after an incident. The nature of our study, which used already available register-based information, did not allow us to control for other factors.

To the best of our knowledge, our study is the first to document the overall characteristics of HEMS patients in Italy after the fatal crash in Monte Cefalone.

6. Conclusion

The retrospective study of HEMS missions in L'Aquila highlights several significant operational and organizational adjustments following the Monte Cefalone incident. These adjustments reflect a commitment to improving safety and maintaining effective emergency response capabilities in challenging environments.

After the incident, the HEMS system showed an increased rate of mission cancellations, particularly due to adverse weather conditions, which may reflect a more cautious approach to mission dispatch. This shift aligns with stricter safety protocols to reduce risks associated with limited visibility in mountainous regions. The addition of a second pilot also illustrates an organizational adjustment aimed at enhancing flight safety. The study documented a reduction in primary rescues and an increase in complex rescue operations (e.g., SAR missions), indicating that the HEMS adapted its focus toward more specialized missions. These operational changes suggest an evolving role for HEMS in environments where ground emergency medical services (GEMS) face limitations. Findings reveal that the HEMS missions after the incident increasingly took place in urban remote areas [17,18] rather than mountainous terrain, which might reflect an organizational response to safety concerns in harsher environments. The demographic consistency of patients (e.g., age, gender) suggests that these operational changes were implemented without impacting the range of patients served. The study observed a decrease in mission volume during 2019–2020, which coincides with the COVID-19 pandemic. This reduction likely reflects a temporary decrease in outdoor activities and emergency service demand, a factor that underscores the sensitivity of HEMS operations to broader societal and environmental conditions.

These findings provide a foundation for assessing and refining HEMS protocols. The shift toward increased safety measures, such as stricter weather-related cancellations and the addition of an extra pilot, highlights the system's responsiveness to risk. These insights may inform best practices for HEMS in other regions with similar geographical and environmental challenges. Future studies should consider multi-regional data to broaden the understanding of HEMS adaptations. Incorporating psychological and individual-level responses, if available, could also provide a more comprehensive view of how such incidents affect the HEMS crew and community trust in air medical services.

CRediT authorship contribution statement

Barbara Pizzi: Writing – review & editing, Conceptualization. **Vincenza Cofini:** Validation, Software, Formal analysis, Data curation, Writing – review & editing. **Stefano Necozione:** Validation, Data curation, Interpretation data. **Andrea Fiora':** Investigation. **Martina Mancinelli:** Writing – original draft, Visualization. **Gino Bianchi:** Data curation. **Emiliano Petrucci:** Writing – review & editing, Validation, Resources, Project administration, Interpretation, Data curation. **Franco Marinangeli:** Supervision.

Data availability statement

The datasets generated during and/or analysed during the current study are not publicly available due [the decedents' proxies or legal surrogates have reserved all right on datasets] but are available from the corresponding author on reasonable request.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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.

Acknowledgements

We acknowledge Giacomo Sollecchia and all staff of "Luca Tonini" Simulation Center, (Department of Life, Health and Environmental Sciences, University of L'Aquila, L'Aquila, Italy), for their support in data collection.

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