

# Stability of Emergency Medications During Simulated Extreme Cold: A Controlled Environmental Study

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## Study aims and background

- Ensuring the stability of emergency medications during extreme environmental conditions is critical for patient safety in prehospital settings such as helicopter emergency medical services (HEMS) and alpine rescue, where temperatures may fall far below recommended storage ranges.
- Our overarching goal is to determine whether emergency medications retain  $\geq 90\%$  of their labeled concentrations when exposed to conditions that challenge standard storage recommendations.

## Methods

- A controlled environmental study was conducted at the terraXcube, a high-fidelity climate simulation facility at Eurac Research in Bolzano, Italy. Medications—Dexamethasone, Ketamine, Rocuronium, Epinephrine, Norepinephrine, Naloxone, Amiodarone, and Acetazolamide—were stored within an Ampullarium placed in mountain rescue backpacks. The ampoules remained sealed throughout the experiment. The drugs underwent six cycles of exposure, consisting of 45 minutes at  $-15^{\circ}\text{C}$  followed by 15 minutes at  $+18^{\circ}\text{C}$ , to mimic temperature fluctuations encountered during extended rescue operations. Stability was assessed through visual inspection for physical changes (e.g., crystallization, phase separation) and chemical analysis using mass spectrometry, with results expressed as a percentage of the reference concentration.

## Results



**Figure 1.** Simulation of prehospital emergency care under high-fidelity scenarios in the terraXcube. (a) Patient simulating a casualty during mountain rescue. (b) Rescue team performing advanced life support on a mannequin at  $-15^{\circ}\text{C}$  and 10 m/s wind inside the chamber. (c) Team operating in full gear under simulated alpine conditions.

**Figure 2.** Study drug performance. Concentration stability of emergency medications following repeated exposure  $-15^{\circ}\text{C}$  for 45 minutes, interspersed with 15 minutes at  $+18^{\circ}\text{C}$ . Bars represent the percentage of labeled drug concentration retained. The red line marks the 90% stability threshold.

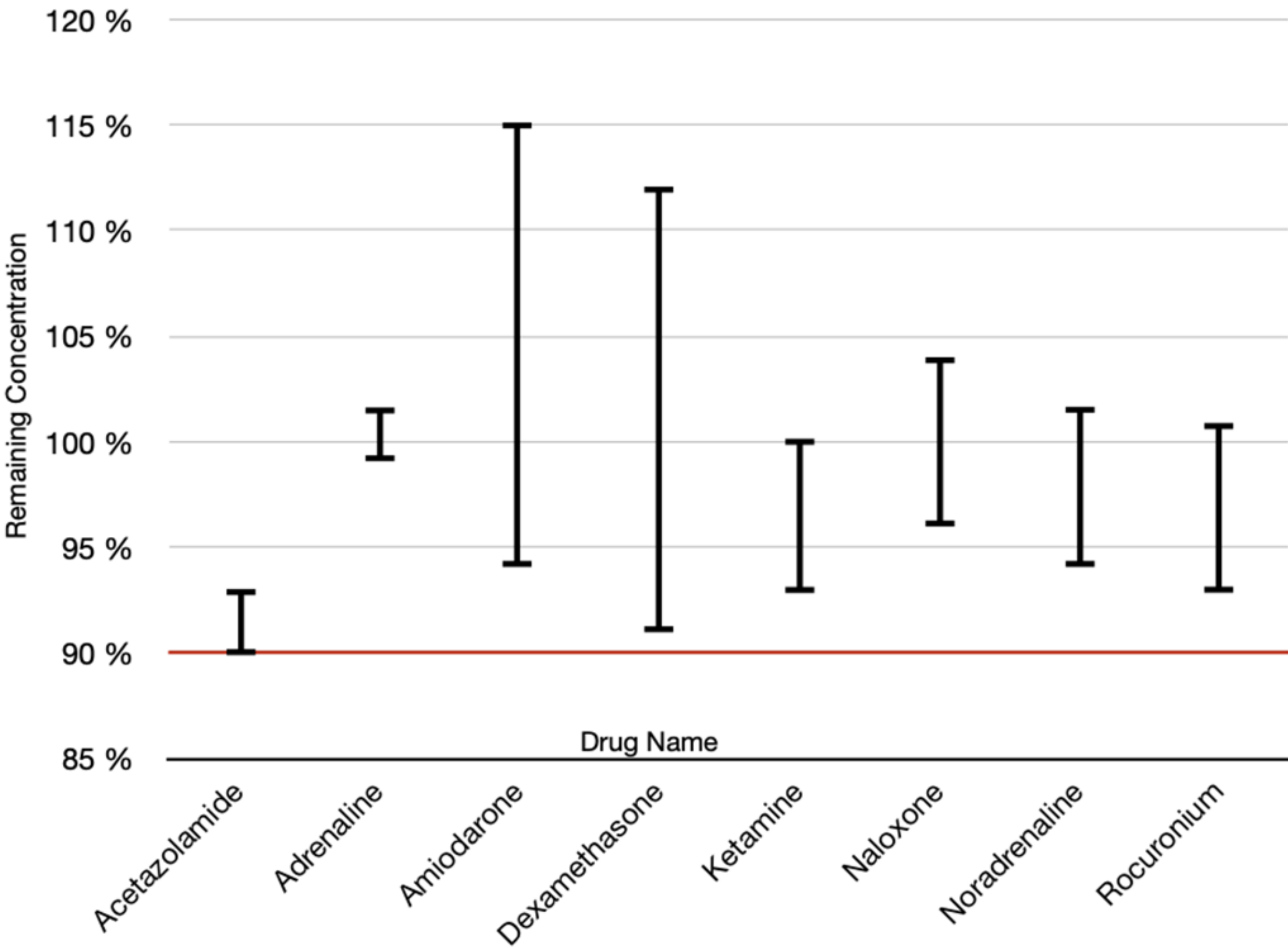


Table 1. Study drugs. Manufacturer Information and Storage Conditions			
Drug name	Brand name (Manufacturer)	Concentration	Manufacturer required storage conditions
Epinephrine	Adrenalin Sintetica (Sintetica SA, Mendrisio, Switzerland)	1mg/ml	Store at room temperature (15-25°C). Protect from light.
Norepinephrine	Noradrenalin Sintetica (Sintetica SA, Mendrisio, Switzerland)	1mg/ml	Store at room temperature (15-25°C). Protect from light.
Amiodarone	Amiodaron Labatec (Labatec Pharma SA, Meyrin, Switzerland)	150mg/3ml	Store at room temperature (15-25°C). Do not refrigerate. Protect from light.
Midazolam	Midazolam Sintetica (Sintetica SA, Mendrisio, Switzerland)	15mg/3ml	Store at room temperature (15-25°C). Protect from light.
Fentanyl	Fentanyl Janssen (Piramal Critical Care Limited, London, Rueschlikon, Switzerland)	0.1mg/2ml	Store at room temperature (15-25°C). Protect from light.
Naloxone	Naloxon (OrPha Swiss GmbH, Küsnacht, Switzerland)	0.4mg/ml	Do not store above 30°C. Do not freeze. Protect from light.
Acetazolamide	Diamox Trockensub (OM Pharma Suisse AG)	500mg	Store at room temperature (15-25°C).
Ketamine	Ketamin Sintetica (Sintetica SA, Mendrisio, Switzerland)	100mg/2ml	Store at room temperature (15-25°C). Protect from light.
Rocuronium	Rocuronium Fresenius (Fresenius Kabi AG, Kriens, Switzerland)	100mg/10ml	Refrigerate (2-8°C). Can be stored a maximum of 12 weeks without refrigeration at a temperature of 8-30°C. Do not refrigerate after the medication has been removed from refrigeration.



## Conclusions

- Our study demonstrated that emergency drugs remained stable during extreme cold conditions, including repeated freeze-thaw cycles, when stored in sealed Ampullarium bags.
- This evidence suggests that, with optimized storage protocols, medications used in pre-hospital rescue operations may remain effective even in environments that exceed standard storage recommendations.