



Clotting at the Extremes: Venous Thromboembolism Across Altitude, Travel, Spaceflight, and Remote Expeditions

Kindalem Fentie, M.D¹, Sarah Spelsberg, M.D¹ , Michael Harrison, M.D, Ph.D¹, Dana Herrigel, , M.D¹

¹1 Department of Aerospace Medicine, Mayo Clinic, Jacksonville, Florida

INTRODUCTION

Venous thromboembolism (VTE) includes deep vein thrombosis and pulmonary embolism.

- Venous stasis
 - **Prolonged sitting, immobilization, confinement, and altered flow in microgravity.**
- Hypercoagulability
 - **Hypoxia, hemoconcentration, inflammation, and individual predisposition.**
- **Endothelial stress**

Extreme environments as risk multipliers

High altitude, long travel, spaceflight, and remote expeditions combine environmental stress with limited diagnostic and evacuation capability. Risk concentrates in susceptible travelers

METHODS

- Structured review: PubMed, Scopus, Web of Science (2000–2026)
- Included human studies, reviews, prevention trials, case reports, NASA/ESA guidance
- Synthesized narratively using Virchow's triad

Table 1: Risk, Mechanism and prevention of VTE aacross different settings

Setting	Relative risk / evidence	Dominant mechanism	Key preventive
Long-distance travel	RR ~2.8; +18% per 2 h; ~1/4,600 flights >4 h	Immobility/venous stasis (± mild hypobaric hypoxia)	Ambulation, aisle seat, GCS; LMWH for high-risk
High altitude	Significantly ↑ VTE/DVT/PE vs low altitude	HIF-1α–driven hypercoagulability (NLRP3/IL-1β, transferrin, TF/FVII)	Altitude-specific risk stratification; guidelines under-tested
Spaceflight	Single reported IJV thrombus; risk unquantified	Cephalad fluid shift → IJV stasis/distension; ↑fibrinogen, endothelial injury	Optimize imaging/biomarker s; risk in high-risk crews unknown
Remote expeditions	No direct data identified	Composite: stasis + hypoxia + cold + trauma/dehydration	Extrapolated stasis/hypoxia countermeasures

RESULTS

- ✓ **Altitude:** a Skardu cohort of 539 evacuated individuals found VTE in 15.9%
- ✓ **Air travel:** risk roughly doubles after 4+ hours, yet absolute risk stays around 1 in 6000
- ✓ **Spaceflight:** an ISS astronaut had an internal jugular vein thrombosis diagnosed in 2017, and about a quarter of surveilled crew showed left jugular venous stasis
- ✓ **Expeditions:** case reports of fatal DVT/PE in unacclimatized trekkers

DISCUSSION

- Stasis dominates in travel and spaceflight; hypercoagulability dominates at altitude
- Absolute risk is low per exposure but may compound across combined exposures
- Isolated settings limit diagnosis and treatment, which raises the stakes
- Shared prevention: mobilization, hydration, pre-exposure risk screening, targeted prophylaxis
- **Gaps:** few prospective trials, small spaceflight cohorts

CONCLUSIONS

- ❖ One framework explains VTE across all four environments
- ❖ Prevention is largely extrapolated from terrestrial guidelines
- ❖ Priorities: prospective data and environment-specific protocols

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