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Injection Fluid Dynamics on Ultrasound During a Simulated Peripheral Perineural Nerve Block on a Meat Model in Lunar Gravity: A Comparative Ultrasound-Guided Parabolic Flight Study

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Lunar Block

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We use this protocol and it's working. Validated protocol for ESA's 88th parabolic flight Campaign

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Disclaimer

No conflict of interests to declare

Abstract

Peripheral nerve blocks have emerged as a superior option for regional anesthesia, often outperforming oral medications and general anesthesia in terms of tolerance and efficacy (4).
While our first study of the flight campaign focuses on the Pericapsular Nerve Group (PENG) block (3), the primary objective of the study described in this study protocol is to analyze the injection and diffusion dynamics of fluids during a procedure simulating a peripheral nerve block, particularly a perineural block (5), comparing simulated lunar gravity (0.16 g) to terrestrial gravity (1 g). This is achieved using ultrasound imaging following the injection of saline solution (NaCl) into an inert model composed of porcine muscle tissue (intended for human consumption) (1, 2). This model has been selected for its closer approximation to human tissue compared to synthetic models, containing different fascial planes and a replicated nerve, mimicking human muscle echogenicity (2).
The relevance of this research lies in addressing the medical challenges that will arise during future lunar space missions, where pain management and treatment of joint trauma will be critical, especially in the absence of onboard specialists. The perineural block, a targeted regional anesthesia technique, provides an effective and minimally invasive approach well-suited to the unique constraints of the space environment. It holds the potential for continuous local anesthesia via catheter placement, enabling extended nerve blockade. Examples include the femoral continuous peripheral nerve block or the infraclavicular continuous peripheral nerve block (5), which may be particularly valuable for future applications in space medicine.

Troubleshooting

Title

1 Fluid Dynamic or Needle Injection in a Meat Model During a Simulated Peripheral Perineural Nerve Block in Lunar Gravity: A Comparative Ultrasound-Guided Parabolic Flight Study

Introduction

2 Peripheral nerve blocks have emerged as a superior option for regional anesthesia, often outperforming oral medications and general anesthesia in terms of tolerance and efficacy (4).
While our first study of the flight campaign focuses on the Pericapsular Nerve Group (PENG) block (3), the primary objective of the study described in this study protocol is to analyze the injection and diffusion dynamics of fluids during a procedure simulating a peripheral nerve block, particularly a perineural block (5), comparing simulated lunar gravity (0.16 g) to terrestrial gravity (1 g). This is achieved using ultrasound imaging following the injection of saline solution (NaCl) into an inert model composed of porcine muscle tissue (intended for human consumption) (1, 2). This model has been selected for its closer approximation to human tissue compared to synthetic models, containing different fascial planes and a replicated nerve, mimicking human muscle echogenicity (2).
The relevance of this research lies in addressing the medical challenges that will arise during future lunar space missions, where pain management and treatment of joint trauma will be critical, especially in the absence of onboard specialists. The perineural block, a targeted regional anesthesia technique, provides an effective and minimally invasive approach well-suited to the unique constraints of the space environment. It holds the potential for continuous local anesthesia via catheter placement, enabling extended nerve blockade. Examples include the femoral continuous peripheral nerve block or the infraclavicular continuous peripheral nerve block (5), which may be particularly valuable for future applications in space medicine.

Objective

3 To analyze the injection and diffusion dynamics of fluids under lunar gravity during an NaCl injection, simulating a peripheral perineural nerve block, using a non-viable tissue model.

Primary Outcome

4 Primary: injection spread area of fluid dispersion during injection measure on ultrasound

Secondary:

	A	B	C	D	E
	Video	Volume of anesthetic used [ml]	Volume of anesthetic used [ml]	Total injected volume per block	Direct observation
	Ultrasound	-	Peri-nerve fluid diameter [mm] in all planes	“Halo sign” from nerve to lateral border of fluid injection.	Echographic analysis
			Circumferential coverage [%]In all planes	Percentage of the nerve circumference surrounded by the injectate.	
			Quadrant distribution [# or %]In all planes	Number or proportion of anatomical quadrants around the nerve occupied by fluid.	
	Ultrasound		Injection depth variance [mm] in all planes	Depth range of the fluid spread around the nerve.	Echographic analysis
	Ultrasound		Nerve-to-needle distance [mm]	From nerve to needle tip (closest point during injection).	Echographic analysis
	Ultrasound		Nerve-to-needle angle [°]	From transverse nerve axis to needle tip axis (at start of injection).	Echographic analysis
	Ultrasound	Nerve perforation rate [%]	Nerve perforation rate [%]	Needle nerve puncture (based on	Echographic analysis

	A	B	C	D	E
				US recording) over attempts.	
	Ultrasound		Fluid spread rate (e.g., mm/sec or cm^2/sec). in all planes	Measured during the complete parabola after completion of injection	
			Fluid spread direction (e.g., mm/sec or cm^2/sec). in all planes	Vector of fluid movement relative to the nerve, indicating the direction in which the injectate extends most prominently.	
	Ultrasound		Symmetry of injection [%] in all planes	Ratio of fluid spread on either side of the nerve.	Echographic analysis

Ethical Approval

5 This study was reviewed and approved by the Institutional Review Board (IRB) of AP-HP Henri-Mondor University Hospitals, France, under IRB number 00011558 and approval number 2025-213. The committee issued a favorable opinion on July 10, 2025, concluding that the protocol does not involve human subjects as defined by the French Public Health Code (Article R1121-1, amended by Decree No. 2017-884 of May 9, 2017) and therefore does not fall under the jurisdiction of a Human Protection Committee. Furthermore, the research was recognized as having significant scientific and medical value while adhering to ethical standards concerning patient protection. Compliance with applicable data protection regulations has also been confirmed.

Methods

6

7 1. Methods & Operational setup of the procedure

Ultrasound imaging will be used to evaluate fluid spread patterns, providing insight into how gravitational differences influence injection dynamics.

These tests will take place during the final five parabolas of the first flight (P26–P30), allowing for 5 measurements under lunar gravity. An equivalent number of injections will be performed on the ground under normogravity for baseline comparison.

The meat model, consisting of 5 smaller meat models, will be placed inside a specially designed glovebox during normogravity phase, providing a time window of 5 minutes between P25 and P26. Materials for hygienic purposes will be put in place (probe cover, handgloves). All injections will be performed by an anesthesiologist. A total of two different anesthesiologists will perform the procedure.

During the flight, several operators are assigned to four distinct roles:
Primary operator: Positioned next to the glovebox, this operator performs the injection in an ergonomic posture, stabilizes their hands within the glovebox, inserts the needle under ultrasound guidance.
Assistant operator: Adjusts monitor according to the instructions of the primary operator. Ensures that imaging is accurately recorded and documented, makes sure that outcome measures are considered. This operator administers the injections while the primary operator holds the needle and probe in place.