Advancing Astropharmacy: PAR Model and Space Pharmacy Council to Preparing Pharmacists for Space Missions

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Dear Editor,

In my previous letter[1], I highlighted the importance of equipping pharmacists with the specialized knowledge and skills necessary to provide effective pharmaceutical care in zero-gravity environments. The article concluded with a call for further research into the emerging field of Astropharmacy. In this letter, I would like to discuss PAR (Participation, Action, Research) model to strengthen research and development in Astropharmacy. Additionally, I propose the establishment of a Space Pharmacy Council to formalize and standardize the professional requirements for pharmacists participating in space missions.

What is Astropharmacy?

Astropharmacy is a relatively new field that intersects pharmacy, space science, and healthcare[2]. It is an emerging interdisciplinary field that focuses on addressing the unique pharmaceutical challenges encountered in space environments. It combines elements of pharmacology, aerospace medicine, and biotechnology to ensure the safe and effective use of medications during space missions. Key areas of focus include:

- **Drug stability in space[3]**: Medications can degrade more rapidly in space due to exposure to cosmic radiation, temperature fluctuations, and the unique conditions of microgravity.
- **Pharmacokinetics and pharmacodynamics[4]**: How drugs are absorbed, distributed, metabolized, and excreted in the body changes in a zero-gravity environment. These variations can affect drug efficacy and safety.
- **Medication delivery systems[5]**: Space missions require new and innovative drug delivery mechanisms that work in microgravity, ensuring that astronauts can take their medications properly.

Overall, Astropharmacy aims to solve these challenges by researching how medications behave in space and developing protocols for the preparation, storage, and administration of pharmaceuticals to astronauts.

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Background on the development of Astropharmacy

Astropharmacy is an emerging field that aims to address the unique pharmaceutical challenges faced in space environments[2]. With the advancement of human space exploration, from low-Earth orbit missions to potential deep-space travel and colonization, there is an increasing need for specialized pharmaceutical care to support astronaut health and safety[6]. Traditional pharmacological models and drug formulations are based on Earth's gravity, atmosphere, and radiation levels, which differ drastically from conditions in space. Factors like microgravity, cosmic radiation, and limited resources aboard spacecraft pose significant obstacles for medication stability, pharmacokinetics, pharmacodynamics, and administration[7]. These challenges necessitate a new framework to guide research and ensure the development of reliable, effective pharmacological solutions tailored specifically for space missions. To meet these challenges, I propose adopting the **PAR (Participation, Action, Research) model** to guide research in Astropharmacy.

PAR Model in Astropharmacy

The PAR model – a collaborative framework – can play a pivotal role in advancing this discipline. By involving pharmacists, healthcare professionals, space agencies, and researchers in the decision-making process, PAR model ensures that all stakeholders can contribute to the shaping of Astropharmacy protocols in space. This participatory approach will pave the way for the identification of critical challenges, the testing of novel solutions, and the systematic documentation of outcomes that can be applied to future space missions (**Figure 1**). PAR model comprises three interconnected components:

1. **Participation in the PAR model**: Involving all key stakeholders, such as pharmacists, space agencies, medical professionals, researchers, and astronauts. Pharmacists can contribute their expertise in pharmacology, clinical care, and patient safety. Space agencies like NASA and ESA that oversee space missions and set healthcare protocols for astronauts and researchers' team can help in conducting scientific studies to understand how space environments affect medication efficacy, stability, and pharmacodynamics. In the last, medical professionals (doctors, nurses, and medical scientists) help pharmacists to design effective healthcare systems for space missions. Collaboration between these groups is vital in developing effective medication protocols for space missions. Each stakeholder brings a unique

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perspective, ensuring that pharmaceutical care in space is both scientifically sound and practical.

2. **Action in the PAR model**: The Action component is where theoretical research will turn into practical, hands-on work. This involves testing the ideas and protocols formulated during the Participation phase and implementing them in real or simulated space environments. Pharmacists and scientists can create simulations of space environments on Earth to understand how microgravity, radiation, and vacuum conditions impact medications. Facilities like neutral buoyancy labs and parabolic flights are used to mimic these conditions. Furthermore, simulations can help in the testing of medication stability, absorption rates, and dispensing mechanisms in zero gravity, enable pharmacists to develop methods to mitigate issues like degradation or inconsistent drug release. Based on the results from the simulations, pharmacist can develop new protocols for space missions. These include methods for drug storage, temperature control, medication dispensation, and dosage adjustments required in space.

3. **Research in PAR model**: This could be the core of the PAR model, where the integration of participation, action, and research leads to the creation of new knowledge in Astropharmacy. Research efforts focus on understanding how space environments affect pharmacokinetics, and pharmacodynamics are crucial for creating protocols that ensure the safety and efficacy of medications. Research can also help in investigating how medications are affected by space conditions such as cosmic radiation, low pressure, and temperature fluctuations. For example, drugs like insulin or certain vaccines may degrade more rapidly in space, necessitating reformulation or special storage solutions. Conducting clinical trials in Earth-based environments that mimic space conditions could be another crucial aspect of research. These trials can help in understanding how different medications behave when the human body is exposed to microgravity for extended periods.

The robustness of the PAR model lies in its cyclical process of action and reflection, which will allow researchers to refine interventions based on real-time feedback. Key elements that can contribute to the model's scientific rigor include:

a. **Iterative process**: PAR model is built on a cycle of continuous improvement. This involves planning an intervention, acting, observing outcomes, and reflecting on results. Each cycle refines the approach, ensuring that the research adapts and responds to findings. This iterative nature will strengthen the reliability and validity of the outcomes.

b. **Data-driven Insights**: The PAR model can provide a strong emphasis on data collection at each stage. Both qualitative and quantitative data can be used to assess the impact of interventions, providing evidence to support decisions. For example, in health settings, patient outcomes are tracked and analyzed, allowing researchers to draw conclusions based on solid empirical data.

c. **Collaborative validation**: PAR model involves stakeholders as active participants, which will add to the robustness of the findings. In a healthcare or pharmaceutical context, collaboration with patients, healthcare providers, and other stakeholders will ensure that diverse perspectives are considered, making the research more comprehensive and applicable to real-world settings.

d. **Transparency and ethical rigor**: The PAR model will provide transparency in its process, often documenting every stage of participation, action, and analysis. This transparency can make it easier for other researchers to replicate or build on the work, thereby contributing to the model's credibility and scientific rigor.

In summary, the PAR model application in Astropharmacy promises a robust framework for addressing pharmaceutical challenges in space and ensuring that knowledge gained benefits both current and future space missions.

Space Pharmacy Council

To further advancing the field of Astropharmacy, I propose the establishment of a Space Pharmacy Council (**see Figure 2**). The figure outlines the organizational structure of the Space Pharmacy Council framework, designed to train pharmacists for space missions. The process begins with foundational education in Astropharmacy**,** covering areas essential for operating in space environments. Key subjects include Space Medicine Fundamentals, Pharmacokinetics and Pharmacodynamics in Zero Gravity, Medication Compounding and Storage in Space, and Emergency Medication in Space. After the foundational coursework, pharmacists advance to specialized roles, such as Space Medication Expert, Telepharmacy Specialist, Medication Supply Chain Manager, Space Pharmacovigilance Expert, and Space Pharmaceutical Researcher. Next, candidates undergo a simulated Zero Gravity Training phase, involving Space Mission Observation and a Microgravity Research Project to develop practical skills. Following this, an internship phase offers hands-on experience. After completing these stages, pharmacists work on Research & Thesis requirements, culminating in a Registration Exam under the Space Pharmacy Council's guidance. Once registered, they enter a phase of Lifelong Learning to keep pace with new developments, ensuring their skills remain relevant for space missions.

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The primary objective of the Space Pharmacy Council would be to standardize professional requirements specifically tailored to preparing pharmacists for space missions and provides a collaborative platform that brings together experts from diverse fields such as pharmacology, aerospace medicine, biochemistry, and pharmaceutical manufacturing. This council can also address the development of pharmaceuticals and medical technologies tailored specifically for space missions. This could involve creating new drugs, optimizing existing medications for space use, and exploring innovative drug delivery methods that function effectively in microgravity and to establish rigorous testing and certification standards for pharmaceuticals intended for use in space, ensuring their safety and effectiveness in the challenging conditions of space travel.

The top three most critical challenges pharmacists can face in space also underscore the need for a **Space Pharmacy Council** to address these issues through standardized guidelines, research, and professional training. Here's how each challenge relates to the necessity of establishing a regulatory and advisory body like the Space Pharmacy Council:

1. **Drug stability and degradation in space**

In the space environment, medications are exposed to unique conditions cosmic radiation, microgravity, temperature fluctuations, and prolonged storage durations that can degrade drugs, impacting their potency and safety[3, 8-10]. Currently, there are no universal guidelines for assessing or mitigating these stability issues in space. A Space Pharmacy Council would establish standardized stability testing protocols specifically for space environments, ensuring that only verified, stable medications are sent on missions under the supervision of space pharmacists. The council could also provide guidance on specialized packaging, storage, and quality control measures that protect drug integrity during long-term space travel. Without such a council, the stability of medications could vary by mission, putting astronaut health at risk.

2. **Altered pharmacokinetics and pharmacodynamics in microgravity**

Physiological changes in space, such as fluid shifts, muscle atrophy, and bone density loss, alter how drugs are absorbed, distributed, metabolized, and excreted[11, 12]. This can lead to unpredictable drug effects, requiring adjustments in dosing and formulation to ensure therapeutic efficacy and safety. However, there is limited research and no standardized protocol to address these variations for medications used in space. The council would spearhead research and develop evidence-based guidelines for pharmacotherapy in space**,** addressing changes in pharmacokinetics and pharmacodynamics. By coordinating research with space agencies and pharmacology experts, the council would define dosing recommendations, identify necessary modifications in drug formulation, and create a knowledge base on the physiological impacts of space travel on drug efficacy.

3. **Drug delivery and administration in microgravity**

Microgravity poses unique challenges for drug delivery, impacting traditional methods of administration[13]. For instance, pills may not dissolve properly, inhaled medications may not distribute evenly, and liquid injections require special equipment to prevent dispersion[13]. Without standardized protocols and equipment, drug delivery in space remains inconsistent, which could hinder effective treatment during missions. A Space Pharmacy Council can help in solving these issues and create standardized protocols for drug administration and specialized delivery devices designed for microgravity environments. By collaborating with engineering and pharmaceutical experts, the council could ensure the development and testing of microgravity-compatible drug delivery systems, such as pre-loaded syringes, specialized inhalers, and microgravity-friendly pill formulations.

To summarize, the **Space Pharmacy Council** would play a pivotal role in preparing pharmacists for the unique demands of space missions, providing specialized training, establishing standards, and fostering research. With a robust organizational structure and targeted training programs, the council would not only standardize pharmaceutical practices for space exploration but also pave the way for pharmacists to make meaningful contributions to the health and safety of astronauts.

Conclusion

In conclusion, implementing the PAR (Participation, Action, Research) model within Astropharmacy research will provide a structured, collaborative approach to addressing the unique pharmaceutical challenges of space missions. Through active participation, innovative action, and systematic research, this model ensures that Astropharmacy progresses with practical, evidence-based solutions tailored to space. Establishing a Space Pharmacy Council will further support this advancement by standardizing professional requirements, providing specialized training, and fostering research collaboration across disciplines. Together, the PAR model and Space Pharmacy Council will prepare pharmacists to deliver safe, effective pharmaceutical care in space, supporting astronaut health and mission success as we extend human exploration beyond Earth.

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Conflicts of Interest: None

Disclaimer: The statements, opinions and data contained in all publications are those of the authors.

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Figure 1: PAR Mode for advancing Astropharmacy

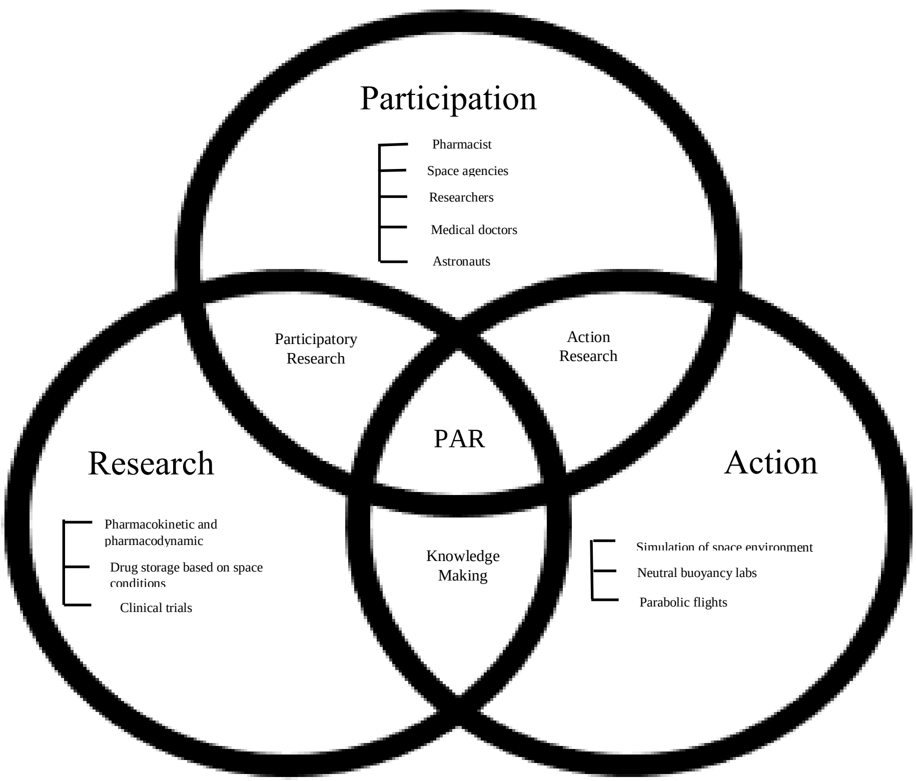

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Figure 2. Space Pharmacy Council tailored to preparing pharmacists for space missions