

The Maturation of Drone-Based Transport for Biological Samples



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Abstract

The transport of biological samples via unmanned aerial vehicles (UAVs) has transitioned from an experimental concept to a reliable operational solution in the pre-analytical phase of laboratory medicine. Recent evidence confirms that drone transport preserves the analytical integrity of routine biochemical and hematological parameters while drastically reducing transport times and carbon emissions. Although challenges such as hemolysis control and regulatory frameworks remain, UAV-enabled transport is rapidly maturing into a fast, sustainable, and dependable alternative to traditional road logistics.

Keywords: Drone; Biological Samples; UAV

To the Editor

The last decade has witnessed a remarkable transformation in the pre-analytical phase of laboratory medicine, driven in part by the emergence of unmanned aerial vehicles (UAVs) as a viable transport modality for biological specimens. What began as a series of proof-of-concept experiments have evolved into robust, realworld implementations demonstrating that drone transport can preserve analytical integrity while addressing longstanding logistical challenges. Recent evidence, including the comprehensive realworld evaluation by Calomarde-Pastor et al. (2026), suggests that drone-based transport is no longer an experimental curiosity but a maturing component of modern laboratory practice [1].

Progress in Analytical Reliability

Early studies raised legitimate concerns regarding vibration, acceleration forces, temperature fluctuations, and potential hemolysis during flight. However, multiple investigations have now shown that these factors rarely translate into clinically meaningful analytical deviations. Recent studies have consistently demonstrated that transporting clinical laboratory specimens via drone (including chemistry, hematology, and coagulation

samples) maintains sample stability and yields analytical results comparable to traditional ground transport [2,3].

The newest and most extensive realworld assessment to date provides compelling evidence that drone transport preserves the analytical integrity of 53 biochemical, hematological, and urinary analytes across both stability and pilot phases [1]. Only a handful of parameters, such as LDH and MCH, exceeded reference change values in the stability phase, largely attributable to mild hemolysis, while the pilot phase revealed a small but statistically significant difference in potassium (-1.7%), a deviation well below clinically actionable thresholds [1]. These findings reinforce that drone transport, when properly temperature-controlled and packaged, is analytically comparable to conventional road transport.

Operational and Logistical Advantages

Beyond analytical performance, drones offer transformative operational benefits. Traditional road transport is vulnerable to traffic delays, geographic barriers, and inconsistent delivery times; factors that disproportionately affect remote primary care centers and contribute to sample rejection due to prolonged preanalytical intervals. Calomarde-Pastor et al. reported a

reduction in transport time from 110 minutes by road to just over six minutes by drone, a dramatic improvement with direct implications for sample viability, turnaround time, and equity of access across regions [1].

Moreover, drone transport aligns with sustainability goals. Stierlin et al. (2024) quantified the carbon footprint of drone transport and found it substantially lower than that of combustion engine vehicles, supporting the integration of UAVs into green laboratory initiatives [4].

Remaining Challenges and Future Directions

Despite these advances, several challenges remain before drone transport can be fully integrated into routine laboratory workflows:

- **Hemolysis control:** Although recent studies show comparable hemolysis rates between drone and road transport, occasional increases -particularly in LDH- highlight the need for optimized payload damping and vibration control.
- **Environmental variability:** Most published studies were conducted in limited geographic and climatic contexts. Broader validation across extreme temperatures, humidity levels, and altitudes is essential.
- **Regulatory frameworks:** Airspace regulations, safety protocols, and certification requirements vary widely across countries, influencing scalability.
- **Workflow integration:** Laboratories must redesign preanalytical logistics, including sample tracking, chain of custody procedures, and contingency planning for flight interruptions.

Nevertheless, the trajectory is clear: drone transport is transitioning from experimental to operational, supported by a

growing body of evidence demonstrating its reliability, efficiency, and sustainability.

Conclusion

Laboratory medicine stands at the threshold of a logistical paradigm shift. The cumulative evidence from the past decade indicates that drone transport has matured into a dependable alternative to road-based systems. As healthcare systems seek faster, greener, and more equitable diagnostic pathways, UAV-enabled transport offers a compelling solution. Continued research across diverse environments and patient populations will further refine its role, but the foundation for widespread adoption is now firmly established.

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