Innovative blood transfusion strategies to address global blood deserts: a consensus statement from the Blood Delivery via Emerging Strategies for Emergency Remote Transfusion (Blood DESERT) Coalition

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In rural settings worldwide, many people live in effective blood deserts without access to any blood transfusion. The traditional system of blood banking is logistically complex and expensive for many resource-restricted settings and demands innovative and multidisciplinary solutions. 17 international experts in medicine, industry, and policy participated in an exploratory process with a 2-day hybrid seminar centred on three promising innovative strategies for blood transfusions in blood deserts: civilian walking blood banks, intraoperative autotransfusion, and drone-based blood delivery. Participant working groups conducted literature reviews and interviews to develop three white papers focused on the current state and knowledge gaps of each innovation. Seminar discussion focused on defining blood deserts and developing innovation-specific implementation agendas with key research and policy priorities for future work. Moving forward, advocates should prioritise the identification of blood deserts and address the context-specific challenges for these innovations to alleviate the ongoing crisis in blood deserts.

Introduction

Millions of people continue to die of haemorrhage and anaemia in settings across the world that are without access to sufficient blood for transfusion.[1] For trauma-related injuries, obstetric haemorrhages, nutritional and hereditary anaemias, and surgical care, blood transfusion is a crucial component of management. There is an annual 102 million unit blood shortage in low-income and middle-income countries (LMICs): every single country in sub-Saharan Africa and south Asia is in deficit.[2] In many rural settings, hundreds of millions of people live without access to any blood; the only hospitals with stocked blood banks are hours away in an urban centre. These settings are blood deserts: areas of the world where there is no reliable access to blood transfusion. If a patient in need of blood presents to a facility in a blood desert, their options are restricted.

Existing blood banking technology is logistically challenging, expensive and, despite decades of progress in transfusion medicine, remains unavailable in many of the world's poorest settings.[3] There is an urgent need for a change in approach to blood deserts prioritising contextually appropriate strategies that enable safe and timely access to blood in the short term while longer term strategies to extend blood bank networks continue. Three emerging strategies that might help alleviate the crisis in blood deserts are: (1) civilian and community walking blood banks (WBBs), (2) intraoperative autotransfusion (IAT), and (3) drone-based blood delivery (DBD). These technologies each address different pressure points in the transfusion continuum. WBBs are a just-in-time emergency transfusion practice where community members are called on for immediate donation and point of care, with rapid diagnostic testing (RDT) used to screen the blood for transfusion-transmitted infectious agents (TTIAs) before transfusion, which can address issues of both blood collection and delivery in urgent situations. IAT collects a patient's blood during surgery, filters it, and transfuses it back to them, focusing on emergent situations in the operating room with major blood loss and transfusion needs. DBD, which involves the creation of a service network, with a storage hub as a blood bank and drones as the delivery vehicles, addresses blood distribution challenges. Nonetheless, each strategy is in various stages of development and their suitability to different blood desert contexts is unclear.

To accelerate consensus on research, implementation, and policy agendas for improving blood availability in blood deserts, a group of interdisciplinary experts convened repeatedly via video conference between January and April, 2023 and met in a hybrid meeting hosted in Cambridge (MA, USA) in April, 2023. The objective of the process was to formally define the term blood desert, identify knowledge gaps, and develop an appropriate research and policy agenda for implementation of WBBs, IAT, and DBD in such settings. This statement synthesises the discussions held during the meeting and outlines consensus recommendations for alleviating the mounting crisis in blood deserts. The group comprised clinicians from LMICs and high-income countries (HICs) across multiple specialties (surgery, obstetrics, general practice, and general and military transfusion medicine, many with roles in policy making and funding), and industry experts, researchers, and patient advocates.

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Methods

Participants

17 delegates (table) were invited to participate in an exploratory process centred on three innovative strategies in blood transfusion for blood deserts: WBBs, IAT, and DBD. Delegates were selected for their expertise in surgery, transfusion medicine, public policy, work with funding organisations, patient advocacy, industry, innovation, and implementation experience in low-resource settings. Ten (58%) of the delegates came from LMICs, with the remaining seven (42%) from the USA. 13 (76%) of the delegates had clinical expertise in transfusion medicine, surgery, haematology or oncology, pathology, or general medicine. The four non-clinical participants were experts in health policy, research, and public health. Delegates had an average of 17 years of experience, ranging from 5 to 30 years. Multiple delegates had more than one scope of expertise. Delegates were divided into three working groups, each centred on one innovative strategy, and with a team of research assistants.

Process

An exploratory process for each innovation was conducted over 8 weeks. Two virtual workshops were held with the entire delegate and research assistant team in January and March, 2023 to facilitate discussion between delegates. The working groups also held weekly internal calls where delegates guided literature reviews and participated in semi-structured interviews for the development of white papers. Literature reviews included published academic materials and grey literature. The inclusion of grey literature was to better understand the commercial and non-academic landscape of work, recognising that rural and informal applications of these innovations might go unpublished. In the semi-structured interviews, questions were focused on understanding the participants' experience with the technology, the barriers, and the facilitators and anticipated moving forward with implementation of the technology, parties involved in implementation, and remaining gaps in knowledge on the effectiveness of technology. Barriers and facilitators for implementation were further explored by examining policy perspectives at the hospital, local, and national levels and from the standpoint of clinical providers and patients. Additional experts in the field were interviewed to better understand each technology's commercial and academic presence.

A 2-day hybrid seminar was hosted at the Harvard Radcliffe Institute campus in Cambridge (MA, USA), in April, 2023. On the first day, we conducted group

	Nationality and country income status	Sex	Clinical expertise	Professional expertise	Working group	Years of experience
Dr Yetmgeta Eyayou Abdella	Egypt; LMIC	Male	Medicine and public health	Blood and international health policy	DBD	>20 years in public health
Dr Asma Ali-Awadh	Kenya; LMIC	Female	Medicine and general practice	Sisu Hemafuse trainer and public health expert	IAT	>10 years in clinical health; 6 years in public health
Dr Lucy Asamoah-Akuoko	Ghana; LMIC	Female	Transfusion medicine	National blood banking service	DBD	>20 years in public health
Dr Linda Barnes	USA; HIC	Female	NA	Transfusion medicine researcher	WBB	>30 years in clinical health, research, public health, and health administration
Col Dr Andrew Cap	USA; HIC	Male	Haematology and oncology	Military medicine	WBB	>20 years in clinical health and research
Dr Zara Cooper	USA; HIC	Female	Surgery	Director of the Center for Surgery and Public Health (Boston, MA)	..	>20 years in clinical health and research
Dr Meghan Delaney	USA; HIC	Female	Transfusion medicine and pathology	Professor of transfusion medicine	DBD	>15 years in clinical health and research
Dr Vijay Anand Ismavel	India; LMIC	Male	Surgery	Device development	IAT	>20 years in clinical health and innovation
Dr Gilchrist Lokoel	Kenya; LMIC	Male	Medicine and general practice	County health administrator	WBB	>15 years in clinical health; 8 years in health administration
Dr Joy Mammen	India; LMIC	Male	Transfusion medicine and pathology	Professor of transfusion medicine	WBB	>20 years in clinical health and research
Dr Marie Paul Nisingizwe	Rwanda; LMIC	Female	NA	Global health researcher	DBD	5 years in research
Dr Juan Carlos Puyana	USA; HIC	Male	Surgery	Global surgery researcher	IAT	>30 years in clinical health and research
Dr Nakul Raykar	USA; HIC	Male	Surgery	Global surgery researcher	..	>10 years in clinical health and research
Dr Nobhojit Roy	India; LMIC	Male	Surgery	International health policy	DBD	>30 years in clinical health and research; >10 years in public health
Dr Claude Tayou-Tagny	Cameroon; LMIC	Male	Transfusion medicine	Professor of transfusion medicine	IAT	>10 years in clinical health and research
Ms Caroline Wesonga Wangamati	Kenya; LMIC	Female	NA	Patient advocate and policy expert	WBB	>10 years in health policy and advocacy
Dr Shimian Zou	USA; HIC	Male	NA	Transfusion medicine research	IAT	>20 years in research

DBD=drone-based blood delivery. HIC=high-income country. IAT=intraoperative autotransfusion. LMIC=low-income and middle-income country. NA=not applicable. WBB=walking blood bank.

Table: **Participant details**

discussions defining blood deserts and the barriers and facilitators for implementation of each technology in a blood desert. On day 2, consolidated recommendations for research and policy priorities were presented, with facilitated discussions for group agreement on the language and content.

Results

A complete definition of the term blood desert, and three white papers were developed for each innovative strategy (see appendix pp 3–62), outlining the current state of each innovation, implementation considerations, and gaps in knowledge. These findings served as the basis for the research and policy priorities established for the implementation of each of these strategies.

Defining blood deserts

A blood desert is defined as a geographical region where essential clinical demand for blood components cannot be met at the point of care in a timely and affordable manner, in at least 75% of cases where transfusion is needed. The crucial features of blood availability include the sufficiency of blood to meet demand, the affordability of the blood for the patient, and the time required for a patient to access a transfusion, which includes the time for a patient to reach a facility capable of transfusion and the time required for a transfusion facility to provide blood to the patient.

Blood deserts are created by an absence of reliable access to a stocked blood bank due to a myriad of reasons, from the challenges of a centralised blood transfusion system, low donation rates, and insufficient resources to staff and supply a functional blood bank.[4–7] The existence of a blood desert is not restricted to LMICs; communities in HICs might also experience considerable barriers to access.[8] However, it is estimated that 40% of annual blood donations are collected in HICs, servicing only 16% of the world's population, leaving most of the global community underserved.[9] Moreover, recent modelling studies have shown that the previously proposed donation target rate of 10–20 units per 1000 people is an underestimate of actual need.[10] However, no studies have captured the true need where transfusion services are the most inaccessible. The only metrics assessing access are based on political borders and not geographical constraints.[2] As such, efforts should be made to identify blood deserts with the intention of delineating the scope of the blood shortage within a given region, and characterising communities at the highest risk of morbidity and mortality as a result.

In addition to identifying and mapping blood deserts, blood unavailability metrics (eg, unmet demand and stockouts), should be measured and reported at the facility, regional, and national levels. Several studies have attempted to understand these data, relying on historical data and projection models.[11,12] In Tanzania, researchers sampled hospitals over a 3-month period and extrapolated these data to establish the unmet need of transfusions.[11] Another group conducted a retrospective study of hospitals over 5 years in Eritrea.[12] These studies highlight the challenges that exist in accurately measuring the unavailability of blood (ie, unmet need), including the absence of clarity and consistency in applied definitions of blood demand versus blood need, a change in ordering practices for blood products in the face of scarcity, and the inability to accurately quantify pre-hospital need for blood. Retrospective studies of blood bank transfusion records might not accurately capture true demand. Therefore, facility-level prospective data collection should be performed to ascertain true demand. To accurately assess true blood need, studies should extend beyond the hospital and include the pre-hospital setting and morgue. Standard reporting measures for adverse events from blood transfusion (eg, TTIA or ABO blood group incompatibility reactions), and adverse clinical outcomes due to the absence of blood available for transfusion should be recorded. Research and policy

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See Online for appendix

***Panel 1*: Research and policy recommendations for defining blood deserts**

Research priorities for funding organisations and researchers

- Analyse the geographical distribution of populations, health-care facilities, and blood availability to identify and define blood deserts
- Define methods to accurately capture blood demand and unmet demand in health-care facilities within blood deserts
- Conduct region-specific studies to ascertain the true need for blood and considering factors, such as population demographics, disease prevalence, and medical procedures performed
- Collaborate with local communities and health-care providers to assess the barriers to provision of adequate blood in blood deserts and the effect on clinical care, communities, and health-care providers
- Evaluate the clinical outcomes and adverse effects resulting from blood shortages in identified blood deserts to understand the effect on patient care and health-care outcomes

Policy priorities for national and regional policy makers and transfusion service directors

- Establish standardised protocols and reporting mechanisms for health-care facilities to measure and report instances of blood unavailability and adverse events related to blood shortages
- Implement regional and national monitoring systems to track, analyse, and report data on blood unavailability and its effect on patient outcomes
- Conduct a comprehensive national and regional assessment to identify regions or areas with restricted access to blood supply and transfusion services
- Collaborate with local health-care authorities, blood banks, and community stakeholders to understand acceptability of context-appropriate strategies to address blood unavailability within blood deserts
- Collaborate with relevant stakeholders, such as blood banks, clinicians, and patients, to secure sustainable funding for infrastructure improvements and ensure the efficient functioning and self-sufficiency of blood banks within blood deserts, including promotion of community engagement and awareness programmes to increase blood donation rates and mitigate shortages

recommendations on defining blood deserts are shown in panel 1.

Walking blood banks

WBBs refer to a spectrum of practices, including emergency donor panels and unbanked direct blood transfusion that includes part of or all parts of a just-in-time transfusion strategy. This strategy applies where (1) donors are mobilised in times of emergency, (2) blood is collected and screened for TTIAs with an available, time-appropriate testing process that might include point of care or RDTs, and (3) universal donor or type-specific (with appropriate crossmatch testing) fresh whole blood is transfused to patients with emergent needs. This approach has been used in various contexts worldwide including, quite prominently, in the military context (see appendix pp 3–20 for a comprehensive overview and references).

In the context of a civilian low-resource blood desert with chronic blood insufficiency, we consider a WBB to include mobilisation of type-compatible or universally compatible donors from the community or health-care team; point of care with blood screening, RDT for TTIA including HIV, hepatitis B and C, and syphilis; and transfusion of fresh whole blood to the patient after suitable crossmatch (if required). Formal uptake in the blood desert context has been impeded by concerns over the safety of point of care and RDT, and uncertainties over the logistics of safe operation.

Although additional research is needed to validate RDT performance in blood desert environments, blanket, context-agnostic prohibitions against RDT use are harmful to patients in blood deserts where no reliable alternatives for transfusion exist. Guidelines are needed to optimise the safety of the WBB process, including clear delineation of decision-making responsibilities, strategies for informed consent, and incorporation of a quality review process to optimise workflow. Nonetheless, the risk–benefit assessment used to decide when to apply a WBB strategy for transfusion is a clinical decision to be made by clinicians, and that should balance the clinical need for transfusion against the risks of transfusion for that situation.

A WBB cannot replace a robust blood banking system; this strategy should only be enacted for emergency situations when banked, laboratory-screened blood is unavailable, and when the patient is at risk for imminent death or disability from haemorrhage. Panel 2 presents research and policy recommendations on implementing WBBs.

Intraoperative autotransfusion

IAT has existed in various forms for decades, from makeshift collection of blood from the body cavities to built-for-purpose devices designed to collect blood in the operative field and reinfuse it back to the same patient (see appendix pp 21–45 for a comprehensive overview and references). Using the patient's own blood can reduce the need for allogeneic transfusion, the risk of introducing a new infection, and the need for typing, and shorten the time to transfusion. Initial studies exploring various autotransfusion techniques in several hundred patients with low-cost autotransfusion devices in South Africa and Kenya have shown feasibility of use in the low-resource setting and effectiveness in reducing the need for homologous blood products.

However, there continues to be a lack of clarity on the ideal scenario for the use of autotransfusion devices,

***Panel 2*: Research and policy recommendations for walking blood banks**

Research priorities for funding organisations and researchers

- Conduct blood desert community-specific capacity assessments, with qualitative methodology, that include both patients and providers for a comprehensive understanding of the current blood availability and need for emergency measures.
- Allocate resources to support studies that evaluate the performance of rapid diagnostic tests for transfusion-transmitted infections under a variety of environmental conditions within blood desert contexts.
- Encourage the generation, consolidation, implementation, evaluation, and dissemination of protocols and best practices for walking blood banks (WBBs) in emergency circumstances in blood deserts.

Policy priorities for national and regional policy makers and transfusion service directors

- Establish regulatory pathways and legal protections for health-care providers and facilities in blood deserts that follow context-appropriate strategies for WBB-based transfusion when clinically appropriate.
- Encourage hospitals and academic organisations to establish formal context-appropriate processes that clearly define decision-making responsibilities for initiating a WBB process among available staff.
- Develop and provide data management platforms for transfusion operations, encompassing donor communication and haemovigilance. Introduce robust information systems that facilitate efficient management and tracking of data related to recipients of blood from a WBB.

Hospital priorities for blood bank directors, hospital-level administrators, and clinical staff

- Develop comprehensive protocols and guidelines that outline the criteria for activating WBB interventions under emergency circumstances. Clearly define the roles and responsibilities of the clinicians involved, outlining their decision-making authority, and the ethical, legal, and clinical considerations to be taken into account.
- Establish mechanisms for training the workforce in implementing WBB procedures that include best practices, safety protocols, and procedures related to WBB. Emphasise ongoing training and provide resources to ensure continuous improvement and readiness.
- Establish quality improvement and review processes to facilitate learning from activations of and use of the WBB process. Foster a culture of continuous improvement and innovation within the WBB system.
- Standardise the informed consent process to align with local consent procedures and include patients and next of kin as required. Develop a clear and standardised process for obtaining informed consent from patients or their legally recognised representatives, and when this is not feasible given emergency circumstances to save life. Balance compliance with local regulations and ethical standards while respecting the rights and autonomy of patients.

uncertainty of benefit with respect to contaminated fields or specific haematologic conditions such as sickle cell disease, and a paucity of medium-term and long-term patient-level outcomes data.

Nonetheless, given the dire circumstances in a blood desert, autotransfusion should be considered as a salvage strategy when a patient is at risk of imminent death or disability from haemorrhage, as deemed by the operating clinician. Furthermore, in less emergent scenarios when banked blood is unavailable or scarce, planned surgical cases with expected blood loss and without violation of the gastrointestinal tract might be a use case for autotransfusion. To safely and thoughtfully apply this strategy, education, guidelines, protocols, and quality improvement processes are necessary. Panel 3 outlines research and policy recommendations on implementing IAT.

Drone-based blood delivery

Unmanned aerial vehicles, or drones, present a systems-level strategy to address blood deserts (see appendix pp 46–62 for a comprehensive overview and references). Drones can facilitate rapid delivery of standard-of-care blood products without the need for extensive blood banking infrastructure at the receiving facility in the blood desert. A drone can surpass difficult terrain, challenging road conditions due to weather, and traffic-congested streets. DBD can be used as a rapid delivery mechanism in emergency situations, such as maternal haemorrhage, delivering blood from a satellite bank to the site in need, or as an alternative blood banking system for managing storage and distribution of blood products.[13] This model has already been used to deliver blood and other medications in many countries, both HICs (USA and Switzerland) and LMICs (Rwanda, Haiti, the Dominican Republic, and Guinea).[14]

The scope of investments required for DBD are substantial in comparison to the other strategies discussed here. From an engineering perspective, DBD will require further technical development to optimise the safe transport of blood across long distances; however, this is outside the scope and expertise of our consensus and will not be explored here. Nonetheless, DBD might be cost-effective in some contexts and, increasingly so, at scale. Additional research is urgently needed using decision science and cost-effectiveness methods that assess system-level and patient-level outcomes, and that incorporate an appropriate counterfactual that considers, for example, improved road infrastructure or additional blood banks, and the larger health system applications for drones.

Implementation of drone infrastructure is not a standalone intervention, but one that would occur within the context of a broader health system. Drone implementation will need to be accompanied with concerted efforts to augment the existing blood supply, as drones will extend the reach and might reveal previously hidden demand for blood in regions that are newly supplied. Perceptions of the drone programme, including scepticism among the public about the use of drones should be actively explored. Operational considerations including aviation sector regulations should also be considered. Panel 4 presents research and policy recommendations on implementing DBD.

***Panel 3*: Research and policy recommendations for intraoperative autotransfusion**

Research priorities for funding organisations and researchers

- Conduct studies to identify specific use cases to delineate patients who might benefit from autotransfusion and enhance patient selection criteria.
- Investigate the quality and composition of blood collected by autotransfusion in comparison to fresh whole blood collected by standard transfusion protocols, specifically as it relates to length of time in which blood has been outside of the vasculature, the presence of inflammatory cytokines and composition fibrinogen and clotting factors, the presence of contaminating substances, and the effect of this on long-term patient-level outcomes.
- Develop registries to systematically track the use of autotransfusion techniques, variations in procedural approaches, and specific patient cases, including evaluation of time-to-transfusion. These registries will facilitate data collection, analysis, and long-term evaluation of autotransfusion practices, ultimately improving patient management and treatment strategies.
- Support large-scale randomised trials to comprehensively understand the efficacy and safety profile of autotransfusion, with a focus on patient-level outcomes such as mortality, transfusion needs, and postoperative morbidity to guide clinical practice and optimise the use of autotransfusion in diverse patient populations.

Policy priorities for national and regional policy makers and transfusion service directors

- Provide comprehensive support including financial assistance in the form of subsidies or grants to promote the development of medical devices tailored for the low-resource context of blood deserts. Support is needed to incentivise development of affordable health-care solutions beneficial for underserved populations.
- Establish guidelines for medical device development and intellectual property. By establishing transparent and streamlined regulations, policy makers can encourage innovation, facilitate collaboration, and ensure that medical device development aligns with safety, quality, and regulatory standards.

Hospital priorities for blood bank directors, hospital-level administrators, and clinical staff

- Establish and distribute protocols and guidelines to standardise use of autotransfusion in emergency situations. By adopting standardised protocols, hospitals and clinicians can ensure consistent use and documentation related to autotransfusion procedures.
- Establish haemovigilance protocols that integrate into the existing system to ensure appropriate follow-up of patients who receive autotransfusion, which includes monitoring and reporting adverse events, tracking patient outcomes, and conducting regular assessments to identify any potential risks or complications associated with autotransfusion.

Discussion

Blood is an essential medicine and strong health systems depend on the availability of safe and affordable blood for transfusion.[15] Unfortunately, blood transfusion is logistically complex and expensive. The process of blood

***Panel 4*: Research and policy recommendations for drone-based blood delivery**

Research priorities for funding organisations and researchers

- Promote the evaluation of priorities of multiple stakeholders involved in implementing this system-level intervention, including patients and providers who live and work in blood deserts, and a comprehensive study to understand community perceptions surrounding drone delivery services. This research should provide insights into public acceptance, concerns, and expectations regarding the use of drones for health-care delivery.
- Encourage assessment of both system-level outcomes of drone interventions, specifically focusing on the availability of blood and geographic variations in availability, and patient-level outcomes, including metrics such as time-to-transfusion, mortality rates, length of hospitalisation, requirements for patient transfer, and affordability of blood for patients.

Policy priorities for national and regional policy makers and transfusion service directors

- Collaborate with aviation regulators to ensure standards for the safe delivery of medications and blood products via aerial means. While ensuring compliance with aviation safety protocols, vehicles carrying crucial medical supplies must be given priority and ensured timely access to blood desert regions.
- Prepare for an anticipated increase in demand for blood products and take necessary steps to augment the blood supply to ensure the effects of drones. Drone delivery might reveal previously hidden demand for blood products and will spread an existing blood supply over a larger area.
- Partner with appropriate academic organisations to generate a comprehensive cost-effectiveness analysis to fully account for the benefit afforded by drones, including lives saved and morbidity averted, and evaluate alternative strategies for improving the delivery of blood including, for example, increased blood banks, newer road infrastructure, and alternative air transport systems.
- Develop sustainable public–private partnerships to optimise apolitical implementation and long-term maintenance of the intervention. Engaging both public and private sectors and creating transparent, long-term value for each might ensure resources, expertise, and governance structures to sustain and scale the intervention.
- Develop sensitisation campaigns to address public perception and increase awareness about the benefits and safety of alternative delivery methods for blood products. These campaigns should focus on dispelling misconceptions, building trust, and promoting public acceptance.
- Encourage collaboration with law makers and drone developers to create dynamic guidelines around licensing and registration, minimum knowledge requirement, environmental effects, geofencing, privacy rights, and other concerns regarding the commercial usage of drones, that stay abreast of the rapidly advancing drone technologies.

transfusion requires multiple steps including donor recruitment, blood screening, processing, storage to timely distribution, administration, and haemovigilance. Almost invariably in LMICs, there are not enough resources to extend and maintain transfusion in all parts of the country, at all times. Thus, the least accessible and usually poorest regions of the country are often left out of reach of the transfusion system.

Much of the global population might reside in such geographic regions where essential clinical demand for blood components cannot be consistently met, at the point of care, in a timely and affordable manner. We refer to these regions as blood deserts. Blood deserts are poorly defined and not measured within global frameworks for transfusion availability. Patients who reside within blood deserts are often the same socioeconomically disadvantaged populations that lack access to strong health systems.[16,17] These populations tend to have restricted political recourse and few advocates. Few clinicians practise in these regions, and those who do practise describe unavailability of blood transfusion as a major barrier to the provision of essential medical and surgical care. This is true for both emergent needs, such as many trauma (eg, road traffic injury with intra-abdominal bleeding) and obstetric cases (eg, peripartum haemorrhage), and for less urgent but crucial needs, where patients are too anaemic to safely undergo needed surgeries (eg, orthopaedic or oncological procedures).[18] These deaths and near-deaths are, by all accounts, entirely avoidable—deaths and disability in otherwise able-bodied young men, women, and children with conditions that are treatable.[19] The mounting human tragedy within the world's blood deserts, however, is largely invisible to the broader clinical and global-health communities. The clinicians who see these patients usually do not have expertise in transfusion medicine, the patients affected are typically poor and with restricted political capital, and transfusion specialists typically practise in or within the vicinity of functional blood banks, which are absent in blood deserts.

The creation of sustainable, accessible blood banking systems in low-resource setting blood deserts will require a framework-challenging, interdisciplinary approach that places the human tragedy of preventable death at its central focus, with the goal to establish a safe, sufficient, and affordable blood supply to all, when needed. Our primary focus was to establish the concept of blood deserts, describe the urgency of the problem from the perspective of patients and providers in blood deserts, and assess three specific strategies—WBBs, IAT, and DBD—that could address these issues today. For the adoption and application of these strategies, active collaboration between scientific and clinical communities is crucial to bridge remaining knowledge gaps and obtain evidence to drive best practice. Successful implementation of these strategies will rely on context-specific adaptation, and to consider factors such as patient cases, hospital and provider capabilities, community health, and national perspectives to establish the appropriate time and place for their deployment. No single strategy will solve this crisis alone; these strategies should be viewed as a complementary set of approaches addressing the diverse challenges associated with improving transfusion access. The figure shows a framework to identify strategy allocations. When considering which strategy to apply, the timeliness of transfusion need should be considered along with the space in which this need is identified. In an operating room, when blood is urgently needed due to an arterial bleed, autotransfusion might be the most

appropriate solution. In contrast, if a mother in labour needs a caesarean section in the next 4 hours, it might be more appropriate to activate a WBB or request a DBD of blood. Although each of these strategies show promise, there is a pressing need for high-quality implementation and research.

It is important to emphasise that these strategies cannot replace the need for a well-established, high-quality blood banking system. Instead, these strategies can have immediate effects on improving access to blood while efforts continue to build sustainable, context-appropriate blood banking systems worldwide. Governments should establish comprehensive transfusion policies aligned to the needs of the communities they serve. As blood—and by extension its components including red blood concentrates, platelets, plasma, and pathogen-reduced cryoprecipitate—is an essential medicine per WHO, ensuring the widespread and safe availability of these products should be at the forefront of health policy. National and local governments should collaborate to develop reliable blood banking systems and provide guidance on the preparation, use, and regulatory oversight of blood.

Blood transfusion is a crucial aspect of health care that affects surgical, medical, oncological, obstetric, paediatric, trauma, and infectious disease practices. Addressing the availability of blood within blood deserts requires an equally diverse, multisectoral, interdisciplinary approach that spans specialty, geography, and traditional roles. The recommendations and themes presented in this Viewpoint can be extended across discussions of blood access and availability in blood deserts. Policy makers and transfusion service directors should account for blood deserts within their purview and measure adverse events from a lack of transfusion. Regulators should establish clear guidance to clinicians to optimise the safety of these interventions while making them available to patients and their providers. Researchers should actively pursue a research agenda that defines safety, best practices, and implementation of these interventions in the lowest resourced settings. We implore the broader academic community and policy makers across the world to join in this important effort to eliminate avertable death from the lack of blood transfusion.

Conclusion

The concept of a blood desert is important for understanding the barriers to access essential medical and surgical care. In a mounting human tragedy, hundreds of millions—if not billions—of patients and their providers live and work in the world's blood deserts, faced with the bleak prospect of receiving or delivering medical care without access to blood. WBBs, IAT, and DBD are interventions that have initial safety data and clinical plausibility and should be urgently considered and implemented where appropriate. In the absence of reasonable alternatives, clinicians should weigh the near certainty of death and disability without access to timely blood transfusion against the lesser risks of transfusion delivered by these mechanisms. Researchers and policy makers should take steps to evaluate, improve, and implement sustainable solutions to the blood crisis.

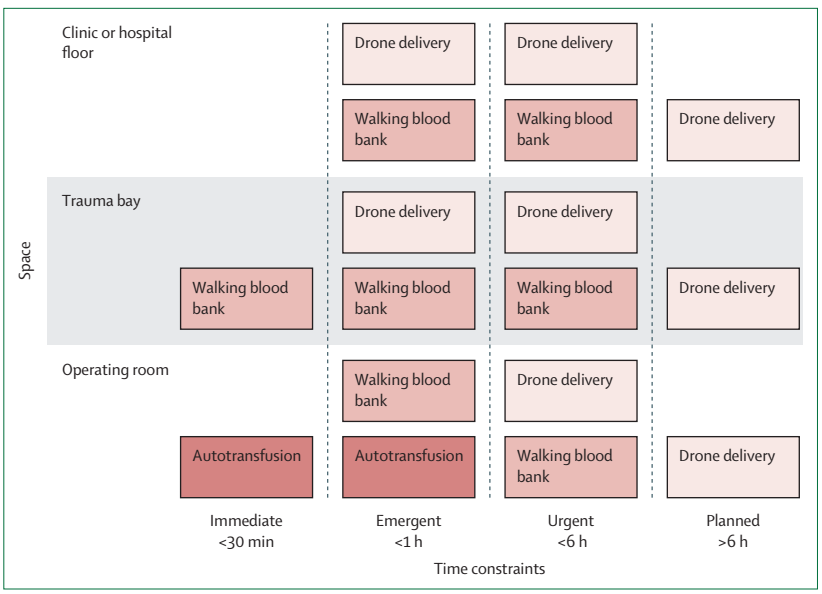

Figure: **Resource allocation strategies**
A conceptual framework to identify the most appropriate innovative strategies for blood transfusion in blood deserts.

Contributors
NPR, VR, LSB, NR, JCP, and MDela contributed to the conceptualisation of the study. NPR, VR, YEA, NR, AA-A, HA, LA-A, LSB, APC, AC, MDela, MDelS, SI, VAI, KJ, GL, JJM, PN, MPN, JCP, CT-T, SV, and CWW contributed to the data compilation and curation. NPR, VR, YEA, AA-A, HA, LA-A, LSB, AC, ZC, MDela, MDelS, SI, VAI, KJ, GL, JJM, PN, MPN, JCP, CT-T, SV, CWW, and NR contributed to the consensus development. NPR and VR drafted the initial manuscript. MDela led development of the figure. NK, RR, and AS critically reviewed, edited the manuscript, and provided support to the study. All authors had responsibility for the decision to submit for publication and approved the final version of the manuscript.

Declaration of interests
We note that YEA works from the WHO Regional Office for the Eastern Mediterranean, and his views expressed in this Viewpoint are personal. We declare no competing interests.

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