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CHALLENGES OF DELIVERING CRITICAL CARE IN LOW-RESOURCE SETTINGS

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Abstract

Critical illness presents a significant global burden and highlights pronounced disparities in health care delivery. Critical care is generally defined as the specialized care of patients with life-threatening injuries and illnesses; it encompasses the identification, monitoring, and treatment of patients with critical conditions (A. Spencer et al., 2023). Patients who require intensive care management often necessitate enhanced monitoring and multidisciplinary treatment by specialists and subspecialists—services that are typically provided only in tertiary care centres in high-income countries (HICs). Critical care is typically delivered in a dedicated physical location, an intensive care unit (ICU), which is linked to emergency departments, operating theatres, and specialist consulting services for other subspecialties.

Intensive care units in low- and middle-income countries (LMICs) are often limited to central referral or major private hospitals in urban areas, despite a much greater burden of critical illness in these regions. Developing stable healthcare infrastructure to support critical care thus represents a major challenge in LMICs. Low-resource settings are characterized by inadequate access to essential medicines and equipment, laboratory support, clean water, reliable power, and consequently trained healthcare staff capable of delivering comprehensive intensive care services. These challenges extend to all aspects of critical care delivery, including workforce training, healthcare infrastructure, medication availability, patient comorbidities, emergency and prehospital services, and ethical considerations surrounding futility and informed consent; innovative solutions to some of these problems are also available.

Keywords 8 words

Critical care delivery in low-resource settings is fraught with numerous challenges that hinder the provision of adequate health services. Access to the limited number of critical care facilities available is a constant challenge. Equipment for basic life support such as oxygen delivery and ventilators are either not available, or costly to maintain and sustain. A critical care skilled workforce is difficult to access, due to lack of adequate training, formal education, and the subsequent retention of staff. The availability of medications, especially essential medicines, is a major concern and contributes to many shortcomings in critical care delivery. Patient characteristics presented for care remain problematic due to both culture and coexistence of numerous comorbidities. Emergency response systems simply do not have the capacity to coordinate and properly establish definitive management of critically ill patients. The aforementioned issues culminate to create serious ethical considerations in the provision of critical care in low-resource settings. Innovative strategies such as telemedicine and critical care training programs can improve global access to high-quality critical care. Other initiatives such as home-based critical care, community paramedicine, and strengthened prehospital models of care present several promising opportunities for increased availability of critical care services in low-resource settings .

1. Introduction

Critical care encompasses the essential resources, skilled personnel, and interventions necessary to provide high-quality care for patients with acute life-threatening illnesses and injuries. These services are critical, as failure to provide timely, aggressive support often results in significant mortality. Robust healthcare systems equipped with appropriate infrastructure, commodities, and workforce can anticipate and manage the majority of such cases. However, healthcare disparities persist in low-resource environments, including economically disadvantaged regions within developing nations, conflict zones, refugee settings, remote and rural areas, and regional hotspots. In such contexts, critical care services may be rudimentary or absent entirely, and where they exist, insufficient resources and poorly trained personnel undermine the effectiveness of interventions. The ongoing COVID-19 pandemic has tended to overwhelm health systems indiscriminately, underscoring the fragility of critical care services in these environments and highlighting the urgency of identifying effective management strategies.

2. Overview of Critical Care

Critical care focuses on supporting failing organ systems during the underlying disease process, redirecting energy to recovery, and mitigating additional injury. Interventions vary with disease severity and progression, encompassing oxygen therapy, intravenous fluids, antibiotic and vasopressor therapy, and endotracheal ventilation. In execution, critical care rests on relatively sophisticated infrastructure and equipment, delivering crucial interventions through highly trained personnel operating within organized systems—hierarchical, multidisciplinary structures designed to coordinate care, create efficiencies of scale, and channel clinical expertise to the bedside. The capacity to deliver services at this level presupposes a functioning emergency and acute care system providing timely identification, resuscitation, and transfer of severely ill patients (A.

Spencer et al., 2023). Influential frameworks for critical care have emerged predominantly in Western countries contrasting sharply with low-resource settings .

3. Defining Low-Resource Settings

Critical care designates a multidisciplinary specialty focused on the comprehensive management of patients experiencing, or at risk of, acute, life-threatening organ dysfunction (I. Losonczy et al., 2021). The specialty aims to prevent further physiological deterioration while simultaneously treating the underlying disease or injury. During care delivery, clinical presentation and resource availability dictate patient management. Critical care encompasses all stages of patient contact, not only those within an intensive care unit (ICU). Low-resource setting (LRS) denotes a health facility or system characterized by a shortage of material, financial, or human resources. While the term traditionally describes settings in low- and lower-middle income countries, it also applies to many facilities in high-income countries . The concept affords a broad perspective of environments with limited resources and is particularly useful when examining critical care delivery in less-developed countries.

4. Healthcare Infrastructure

Health-care infrastructure and basic equipment are less prevalent or are of a lower standard in low-resource settings (A. Spencer et al., 2023). Even within existing facilities—whether they are peripheral or central hospitals—equipment, such as for respiratory or haemodynamic support, is frequently absent or unreliable. Characteristic limitations include those related to water, electricity, essential laboratory investigations, and still more elaborate interventions . The less visible determinants of supply and demand, such as political constraints and cultural and social networks, remain equally important.

4.1. Availability of Facilities

The availability of facilities varies depending on the setting. Remoteness and distance traveled have an impact on patient outcomes in intensive care units. The burden of paediatric intensive care differs between countries, with accessibility to tertiary care influencing outcomes. Priorities in neonatal care remain a concern in developing countries. The effectiveness of primary health care continues to be debated decades after the Alma-Ata Declaration. The capacity of primary health care systems to respond to emergencies, such as floods, is critical. Emergency medical services play a vital role in developing countries, where their effectiveness affects health outcomes. Issues of fairness and equity in the migration of medical professionals are discussed globally. Training programs in disaster triage and humanitarian health, especially for international healthcare workers, are essential. The development of telemedicine networks offers potential for international cooperation, improving disaster response and healthcare delivery .

4.2. Equipment Limitations

ICU availability is a problem in many hospitals around the world, where the number of ICU beds is insufficient for the population. The limited number of ICU beds makes it harder to transfer patients for further management. Doctors and nurses face challenges because they want to admit every deserving patient to the ICU, but the shortage forces them to choose which patients deserve a bed most. The shortage of ICU beds delays admissions and results in complications (Malelelo-

Ndou et al., 2019). Shortages of required equipment such as ventilators are also common. Patients may have to share monitors because of malfunctioning ventilators, and continuous monitoring is not maintained. Equipment is poorly maintained and not serviced regularly.

The availability and distribution of critical care equipment is often limited. Access to essential medicines and equipment requires appropriate services and uninterrupted supplies at both national and facility levels. The WHO Essential Medicines List guides the selection of safe, effective and cost-effective medications for healthcare systems, with emergency lists and guidance also provided during health crises. Expert groups have defined 213 medicines as essential or desirable in critical care, including oxygen, which was designated essential in 2017. Systems for medical equipment are less developed and implementation is inconsistent. Equipment infrastructure such as oxygen ecosystems needs national strategies and long-term financing. Surveys in low-resource countries frequently identify shortages of essential equipment, supplies and medications such as oxygen, vasopressors and antibiotics. These shortages arise because procurement, distribution and consumption require complex logistics that low-resource facilities struggle to maintain, and because funding is limited overall. The lack of provision for analgesic and palliative medications is another concern, which planning and procurement challenges have worsened (A. Spencer et al., 2023).

5. Workforce Challenges

The complexity of critical illnesses and the multifaceted care involved are largely dependent on the specific insult, potential comorbidities, and baseline patient function. Managing such patients requires expert skills and knowledge; however, many low-resource settings lack adequate numbers of healthcare workers and critical care experts. The creation of the Appropriate Resources for Critical Care in Hospitals (ASCCiH) suggests that physicians and nurses working in these environments should possess advanced resuscitation knowledge for critically ill patients and enhanced decision-making skills. A cost-effective approach is the empowerment of general physicians and nurses through critical care education and training to provide competent and quality critical care services.

Retention and further training of critical care personnel in low-resource settings represent an ongoing challenge. Although telemedicine—linking experts from other areas to offer remote support—emerges as a promising solution, workforce shortage extends beyond critical care to all three levels of patient care. Additionally, limited healthcare access in these settings contributes to the delayed presentation of diseases that may otherwise have been managed earlier. Access to critical care in low-resource environments reflects disparities not solely in intensive care beds, infrastructure, and medications, but also in emergency response capacity and coordination of patient transfer to advanced centers.

Patients in low-resource settings face scarcity of essential life-saving or life-sustaining medications due to cost or unavailability. The differing cultural landscape introduces varied perceptions of intervention legitimacy and informed consent, raising new ethical considerations. Awareness of the sarcopenic, asthenic, and malnourished profile of many critically ill patients in low-resource settings should inform the perspectives of global colleagues planning collaborations aimed at

improving outcomes and quality of care. Understanding these nuanced differences can lead to more just and effective resource allocation.

5.1. Training and Education

The delivery of critical care relies heavily on appropriate training and education to equip providers with the necessary knowledge, skills, and attitudes. Critical care is demanding, requiring practitioners to process vast amounts of medical information while making rapid decisions. The increasing complexity and volume of available information render traditional methods of learning—long hours of didactics and reading—challenging, particularly as resident work hours are increasingly limited and clinical demands continue to increase. The growing predominance of non-physician practitioners and the increasing complexity in clinical processes of care make it difficult to define the most appropriate educational approaches to optimise future caregivers and preserve and enhance the skills of the existing workforce. New approaches responding to the learner's needs, the exponential growth in medical knowledge, and ongoing time demands of clinical care are urgently needed. Practical educational methods that can be embedded into the everyday practice of critical care without disrupting clinical workflow and that can be used to improve the efficiency and effectiveness of education for clinicians throughout their careers are extremely attractive (F Joyce et al., 2017).

5.2. Retention of Healthcare Workers

Critical care skills are essential for all levels of care in hospital inpatient settings. The shortage of trained personnel in LRS has been a recognized challenge for decades. This shortage is caused by multiple factors, including lack of local training opportunities, migration to high-resource settings or to private sector jobs, and staff leaving clinical practice altogether. Once basic pediatric life support has been established, ongoing education and supervision are important to sustaining the improvements in outcome. Innovative approaches are needed to achieve high coverage with well-trained staff, particularly in post-graduate training programs, such as web-based teaching and on-site training using a train-the-trainer model.

Innovative use of telemedicine can also enhance supervision, without requiring travel, even at regional centers. After completing a supervised training program, health workers must then be retained in clinical areas. In LRS, a common practice is to rotate doctors to blood bank or project-related duties in busy times of paramilitary services, which moves the doctors from clinical practice to administrative work. Nurses may be recruited from rural regions but not retained.

6. Access to Medications

A reliable supply of commonly used medications is fundamental to any functioning health care system. Even when appreciating the scope of worldwide health care disparities, it is nonetheless striking to recognise that certain medications, such as the World Health Organization (WHO)'s "Essential Medicines", are inaccessible to the majority of the world's countries and their people. The scarcity of these key pharmaceuticals can be so acute that the lack of a penicillin or an oxygen cylinder can become more than an inconvenience: it can, literally, be a life-or-death matter (Loosli et al., 2021).

Compounding the challenge is the elevated cost of pharmaceuticals in low-resource contexts, which may substantially exceed the prices found in more affluent or developed settings. Indeed, over half of the poorest fifth of the world's population lacks any form of financial protection against the cost of health care, and out-of-pocket payments rise in magnitude as the one departs wealthier areas. Moreover, the purchasing of drugs in rural areas and in developing settings often relies more upon shopkeepers or informal drug vendors than upon formal medical facilities. Presumably, the financial and informational burden associated with acquiring pharmaceuticals under such circumstances adds significantly to the difficulty of accessing the medications themselves, suffusing what should be standard medical care with stress and uncertainty.

Ultimately, by the lights of the WHO's universal health coverage targets, to ensure timely access to both a health worker and access to medicines is regarded as a key measure of equitable oral health provision—and, by extension, equitable access to health care more broadly. Sustained efforts to reduce the expense of essential medications and to improve their availability to regions in greatest need thus constitutes a clear, tangible, feasible aim for any programme undertaking the fortification of a critical care infrastructure in a developing context.

6.1. Essential Drug Shortages

Drug shortages impact the ability of clinical teams to effectively care for critically ill patients. Managing drug shortages involves balancing the use of technology and team efforts to minimize patient harm. Shortages hinder the readiness of smart pump libraries and interfere with accurate medication administration. Specific shortages, such as norepinephrine and remifentanil, are associated with increased mortality and difficulties in managing mechanical ventilation in neurocritical care. Addressing drug shortages is essential for maintaining safe and effective treatment, particularly in acute ischemic stroke and other critical conditions (L. Clark et al., 2019).

6.2. Cost Barriers

Cost constitutes a major barrier to critical care access, preventing the delivery of lifesaving treatment and forcing patients and families into catastrophic expenditure or debt, even when services are nominally free at the point of delivery. In many settings, the inability of patients and families to pay effectively limits access to both critical care services and essential medications (A. Spencer et al., 2023).

High infection rates, HIV status, malnutrition, anaemia, and other endemic comorbidities influence patient admission decisions; resource or capacity-limited centres face difficult decisions regarding who receives care when demand exceeds supply . Diabetes mellitus, cardiovascular disease, hypertension, and smoking arise as risk factors in COVID-19 critical illness, while local infection patterns contribute to considerable heterogeneity. Cultural factors also play a significant role in decisions to seek and accept care. Obtaining informed consent for procedures under-training conditions with associated uncertainty introduces additional challenges. Critical illness often manifests late in the disease course, reducing the capacity for successful clinical intervention.

7. Patient Population Characteristics

The patient population in low-resource settings presents another challenge for the delivery of critical care. Patients may have a greater number of underlying chronic comorbidities such as renal

failure, diabetes, and malnutrition. It has been suggested that patients have a stronger spiritual and family influence in healthcare decisions compared with high-resource settings and may lack a proper understanding of the risk–benefits of intensive care unit admission and treatment.

Emergency response systems is an emerging field of research and development in the low-resource setting. Emergency response at the patient, community, and regional level is important for the timely care of the critically ill patient. Low-resource setting prehospital systems generally lack sufficient general capacity for emergency transportation and the coordination between prehospital and hospital emergency care is also problematic. Allocation of scarce resources in critical care often generates unique ethical dilemmas, with decision-making that is challenging for providers as well as difficult to communicate and explain to patients and families. These issues have gained recent attention and continue to require further research.

7.1. Prevalence of Comorbidities

Comorbidities such as HIV, tuberculosis, diabetes, and malnutrition are frequently encountered, impacting the delivery of care and affecting response to treatment. Cultural, language, and religious differences often influence the circumstances around critical illness, decisions related to withholding or withdrawing care, and end-of-life care practices.

7.2. Cultural Considerations

Local beliefs about causes and government-imposed regulations can limit the provision of critical care in low-resource settings (A. Spencer et al., 2023). Health systems are complex social systems, and the success of critical care approaches depends on how well they fit local values. In Ethiopia, a survey of cultural concerns related to critical care found five key issues: communicating with patients, communication about staff, concerns regarding permits and medical certificates, kangaroo care, and Quality Improvement and Patient Safety. Ensuring cultural appropriateness for specific settings is essential for critical care delivery.

8. Emergency Response Systems

Emergency response systems comprise widely accessible prehospital transport, reliable communication and coordination between prehospital providers and receiving hospitals, emergency units able to rapidly assess and stabilize critically ill patients, and interfacility transport systems capable of moving patients between hospitals when necessary (A. Spencer et al., 2023). The implementation and quality of emergency and urgent care systems vary considerably across different regions within the African continent (Kannan et al., 2020) , and high-quality emergency services significantly improve patient outcomes by reducing injuries, deaths, and severe disabilities (F Burke et al., 2014). Consequently, the development of regional policies is essential to guide emergency and critical care delivery in resource-limited settings. More than half of deaths resulting from emergency medical conditions could be avoided through effective prehospital and emergency unit care. The absence of well-defined emergency care systems hampers timely access to life-saving resuscitation and critical care interventions in order to address major causes of death and disability.

8.1. Capacity for Emergency Care

The capacity for emergency care represents a substantial constraint on critical care delivery in low-resource settings. There is wide variation in the organization, quantity, and quality of available emergency care systems worldwide, and capacity constraints have been widely documented in low-resource regions. An assessment of the emergency and urgent care capabilities of health facilities in Western Kenya found that many facilities had significant gaps at all levels of care. Organized trauma management is limited to 30% of secondary level and 0% of primary level health facilities. While basic supplies for wound care and suturing are available in most lower level facilities, other fundamental trauma treatment commodities are widely lacking. Facilities similarly lack the equipment and medicines necessary to provide adequate cardiac care; 50% of higher-level sites have morphine for the treatment of chest pain, but few have functional ECG machines, sublingual nitroglycerine for the treatment of angina, or a defibrillator. Moreover, only 20% of lower-level facilities have glucometers to diagnose hypoglycemia or hyperglycemia, and only about one third of secondary-level facilities can manage diabetic emergencies.

The assessment also notes that no health facility surveyed had clinical guidelines for the identification or treatment of sepsis—a major contributor to in-hospital mortality globally. More broadly, critical care delivery ultimately depends on a functioning referral network with access to appropriate transportation and communication resources. In many low-resource regions, these capabilities are highly limited and poorly coordinated (F Burke et al., 2014).

8.2. Coordination of Services

The coordination of services is challenging in low-resource settings due to the separation of emergency and critical care services and the lack of baseline emergency care infrastructure . Integrating these services with all other medical and public health programs in the community, including long-term follow-up care for survivors, is essential. Warehousing supplies and equipment is a blunt approach because volume on its own rarely equates to increased surge capacity. Facilities must be designed to allow staff and patients to flow to the correct locations efficiently (A. Spencer et al., 2023). The circulation of healthcare workers to various clinical areas helps to ensure capacity and staff morale. A larger-scale event requires coordinating multiple sites and establishing effective command, control, and coordination systems.

Materials must be stockpiled, and any potential barriers to the rapid importing of critical or scarce resources must be removed. Supplies should be pre-positioned as close to facilities as possible to minimize haulage time. The coordinated distribution of resources across not only a single site but an entire healthcare system is required. In-country coordination of national and regional emergency systems is needed alongside international assistance, particularly during the early phases of an emergency before global supply chains can provide appropriate assistance.

9. Ethical Considerations

One of the greatest ethical challenges faced in low-resource settings is the allocation of scarce resources (Kumar et al., 2023). The scarcity of essential medications, equipment, and trained staff makes it necessary to triage and prioritize patients, decisions fraught with profound ethical dilemmas that complicate the delivery of appropriate care. Similarly, the process of obtaining

informed consent becomes more difficult when health literacy levels are low and family members hold primary decision-making power. These considerations arise in the context of the broader constraints already identified—limited healthcare infrastructure, workforce shortages, and inadequate supply of essential drugs—that collectively demand careful, ongoing ethical evaluation to guide critical care practices in such settings.

9.1. Resource Allocation

Availability of critical care facilities (e.g., monitored beds or emergency and very intensive-care units) in low- and middle-income countries (LMICs) has been reported at less than 5 beds per 100,000 population, compared with 5–30 per 100,000 in high-income settings (A. Spencer et al., 2023). In many African settings, major gaps exist in medical records and documentation systems, functional pulse oximeters, suction devices, blood-pressure monitors, and oxygen delivery apparatus. Healthcare workers are often severely overworked, underpaid, and government policies may hinder the establishment of posts without clear funding and support. Medication shortages are common and patients often face considerable out-of-pocket costs for treatment.

9.2. Informed Consent Challenges

Obtaining informed consent requires adequate disclosure, understanding, and voluntariness (M. Morrow et al., 2015). The setting of paediatric critical care complicates valid informed consent and treating a patient without consent may be unethical. Surrogate decision making relates directly to notions of acting in the child's best interests, to protect the vulnerable. Yet in practice the level of involvement sought from children varies and parental decisions may not always be in the child's best interests. And if parental consent is regarded as a legal obligation, a notion that is supported by the South African National Health Act No 61 (Republic of South Africa, 2003), challenges arise when no parent or legal guardian is available to give consent at recruitment. Ethical uncertainty also relates to select aspects of South African law.

In the context of research, the Act's requirement for written consent is at variance with national and international guidelines, which allow for the possibility of verbal consent. Under the Act, obtaining consent from a proxy decision maker in the case of incompetent adults is disallowed or unclear. However, proxy consent is viewed as a reasonable referral of authority by critically ill adult patients. Better alignment between the Act and other research guidelines would be a welcome advance. It is also accepted that in the case of a minor, consent can only be provided by a parent or legal guardian or other person to whom guardianship has been granted. Caregivers or persons deemed to be conservators of the child's best interests in other ways may not provide consent for participation. Since the conjugate notion of assent does not have legal standing, surrogate consent for clinical research has assumed prominence in contemporary guidelines.

10. Innovative Solutions

Healthcare infrastructure is one of the major challenges that underpin the difficulties in delivering critical care in low-resource settings. Whilst lacking a formal definition, low-resource settings typically exhibit systemic vulnerability through one or more of five general characteristics: healthcare infrastructure, workforce, unavailable or unaffordable essential medicines, non-communicable and communicable diseases, and a rapidly growing population (A. Spencer et al.,

2023). In many such settings the availability of an intensive care unit (ICU) is limited, the ICU beds which do exist are typically of lower quality with reduced access to equipment such as continuous positive airway pressure or mechanical ventilation, and basic monitoring may be intermittent or unavailable. For example, there are approximately four ICU beds per million people in Uganda compared with 4000 per million people in the United States. Even within countries, a disproportionate number of ICU beds may be located in less remote urban areas, in non-public, or specialised centres, and remain out of reach for patients in rural areas.

10.1. Telemedicine Applications

Telemedicine delivers healthcare services and education over a distance. It opens new modalities of access to both diagnostic support and continuing medical education (COMBI et al., 2016). Given the widespread availability of mobile phone networks in the developing world and the rapid global spread of smart mobile telephones telemedicine promotes new models for affordable medical care.

Telemedicine networks in French-speaking Africa, such as the RAFT (Réseau en Afrique Francophone Pour la Télémédecine) project, support continuing medical education and tele-consultations between health professionals via a low-bandwidth Internet connection. Other initiatives address staff training, diagnostic telemedicine, and phishing-related challenges in Sierra Leone and Rwanda. Use of SMS applications pertains to disease prevention and raising public health awareness. Services also support hospital doctors in the Middle East via asynchronous telemedicine exchange through email, and programme for rural Nepal India address restoration of local healthcare. Frameworks for optimal selection of telemedicine technologies support patient-oriented health interventions in developing countries. Evaluation methodologies and systematic reviews provide evidence of effectiveness of telemedical services. Development of Electronic Medical Record (EMR) and tele-consultation systems over distributed locations contribute to improved primary healthcare and progress towards universal health coverage in resource-limited settings.

10.2. Community-Based Approaches

Community-Based Approaches Expanding critical care in low-resource settings requires more than ICU building and staff training; well-trained community-oriented providers must be part of a coordinated system to reduce barriers to timely care and to limit pre-ICU patient contact (

11. Case Studies

Austere ICU Case Studies Several case studies inform the organisational characteristics of austere intensive care units (ICUs) established in accordance with the Armed Forces Medical Services Critical Care strategy, as well as military trauma care more broadly (A. Spencer et al., 2023). These examples emphasise the parallels with austere civilian medical systems and the wider humanitarian sector . Advice on setting up surgical intensive care in disaster environments draws on extensive experience of using rapid deployment medical systems in both military and emergency humanitarian circumstances. The experience of UK military intensive care units in Afghanistan, including 12 months in Helmand Province, provides practical guidance on setting up medical systems to provide intensive care in an austere environment. Critical care on Land Rovers, as

developed to satisfy the need for rapid casualty evacuation from the battlefield to a Field Hospital, offers insights into the constraints imposed by working in a non-hospital environment. Critical care for atypical clinical presentations characterises much military medicine, and these lessons are also relevant to civil preparedness. PED-EMC (Paediatric Emergency Mass Critical Care) is conceptually feasible even when paediatric-specific resources are extremely limited. With none of the three regional mass critical care centres yet established, hospital preparedness cannot be assumed. Nevertheless, military medicine illustrates that PED-EMC capability can be built through proactive adaptation of existing civil crisis standards of care and through advances in paediatric disaster medicine. The protection of children, already identified as a major concern internationally, is likely to remain a substantial gap in critical care surge capacity and capabilities for future catastrophes. Several military medical responses to catastrophes provide lessons that can be drawn upon to improve civil disaster response. Initial experiences of emergency surgery in the former Soviet republic of Georgia, conflicts in Uganda and Tunisia, and with the Mass Casualty and Weapons of Mass Destruction Surgical/Trauma Module emphasise the need for detailed reporting of medical management during humanitarian crises. The importance of reconstruction after natural disasters is illustrated by experiences in Indonesia after the tsunami and recent GMC standards underscore the continuing obligation to provide humanitarian assistance. Experiences from Hurricane Katrina also provide insights into medical organisation in response to natural events. Experience of intensive care in resource-poor settings has been documented in Tanzania and Nigeria. As with earlier conflict data, the lack of equipment and of drug therapy restricts both the level and types of care that can be delivered. Critically ill patients present to a variety of healthcare facilities including healthcare centres, district and regional hospitals, and subsistence farmers own livestock. In Navajo culture, for instance, horses symbolise wealth and prosperity, and their loss compounds the broad financial impact of illness on the community. Nigerian refugees in Chad illustrate the impact of health status across neighbouring countries and the importance of critically ill patients within a population group in transition.

11.1. Successful Models in Low-Resource Settings

Critical care is the identification, monitoring, and treatment of patients with critical illness through support of vital organ functions. Most of the world's population lives in low-resource settings: those where the availability of resources is inconsistent and insufficient to adequately maintain or restore health. Critical care is essential for a large proportion of patients who become critically ill; its global availability is therefore a crucial barrier to reducing the extraordinarily high number of deaths that occur daily from otherwise preventable causes (I. Losonczy et al., 2021). Both in the United States and internationally, critical illness is among the leading causes of death and disability, underscoring the extensive burden of disease for which critical care is crucial.

Critical care medicine is a relatively new medical specialty in many countries, and the provision of such care in low-resource settings is associated with extraordinary barriers. These include the capacity and infrastructure of both local and regional health systems; a fundamental lack of critical-care-focused equipment, goods, and medications; a shortage of both specialized and non-specialized staff; the high burden of additional patient and population-level challenges including

poorly controlled comorbidities and traditional, cultural, and financial barriers; the high cost of critical care and its associated medications, supplies, and equipment; the absence of formal prehospital emergency care services; inadequate referral and follow-up pathways; and other limitations . Each of these represents an independent challenge to the delivery of critical care, but each is also closely interconnected with the others. Efforts to improve access to critical care in low-resource settings must therefore consider these multiple, interacting elements, as several have the potential to influence the capacity of the health system to prevent illness progression or to identify, stabilize, and treat patients with acute, potentially reversible conditions.

11.2. Lessons Learned from Failures

Lessons learned from failures highlight the challenges of providing critical care in austere and resource-limited environments, including military and civilian settings. Critical care outside traditional hospital settings, such as in military trauma or disaster zones, requires evolving strategies and practical approaches. Documenting emergency surgery, trauma care, and pediatric critical care during crises helps improve response policies. Lessons from disasters like Hurricane Katrina and experiences in low-resource countries emphasize the importance of adaptive systems, resource availability, and collaborative models. Special attention is needed for pediatric emergency care and the management of severe sepsis in Africa. Improving oxygen delivery and integrating emergency obstetric care into broader health agendas are also crucial aspects of successful disaster and resource-constrained healthcare responses .

12. Policy Implications

Critical care accounts for an increasingly large burden of both infectious and non-communicable disease in low-resource settings, yet relatively little is known about how these services are best delivered in constrained environments (A. Spencer et al., 2023). The Resource-Poor Settings panel advocates for the provision of life-sustaining emergency treatments within all acute care services, regardless of setting, and the development of protocols specifically for low-resource environments should an intensive-care unit be unavailable . Advocacy facilitated by professional societies is necessary to encourage the allocation of sufficient resources toward the provision of high-quality services, and engagement with international healthcare organisations can help leverage political influence.

12.1. Advocacy for Resource Allocation

Never has the need for emergency and critical care medicine been greater worldwide. Yet delivering these services remains a challenge. The World Health Organization's “Summary Hospital Emergency Care Survey” demonstrates the paucity of resources (facilities, medicines, equipment, human resources, and systems) and systems to deliver emergency and critical care in low-income countries. Numerous examples of innovative solutions to improve critical care delivery in low-resource settings exist at every level. Much can be done, especially by practitioners and policymakers with political prioritization and advocacy. Critical care is defined as a multidisciplinary and interprofessional specialty dedicated to the comprehensive management of patients having, or at risk of developing, acute, life-threatening organ dysfunction . It comprises

clinical, diagnostic, and therapeutic modalities; organizational systems and facilities; and ethical, social, and economic aspects of patient care.

This specialty requires a broad field of knowledge, sophisticated technology, and complex clinical protocols within a highly coordinated organization. Low-resource settings constitute generally low-income populations, centers, and countries in which affordable and accessible healthcare is constrained by limited availability of basic equipment, facilities, and workforce . Infrastructure includes the availability of premises, equipment, and general resources (such as water and electricity), while equipment covers everything from defibrillators to roller clamps. Workforce encompasses the number, skills, and availability of medical, nursing, and allied staff. Medicines must be both affordable and available, with an emphasis on essential drugs. The patient population's characteristics cover frequent comorbidities (such as HIV/AIDS, obesity, diabetes, substance abuse, poisoning, and malnutrition), as well as cultural and religious factors influencing delivery and provision of care. Systems and structures represent everything from the emergency response to the outer reaches of the healthcare network, through coordination, referral mechanisms, and communications to the availability of regulations and legislation. Social considerations include the collateral impact of illness on the family and the community, the state of the economy with regard to the patient's earning capacity and livelihood, and political and conflict situations. Partnerships and humanitarian assistance concern the role, structure, and governance of both government and nongovernment players in all aspects of service delivery and reconstruction. Research and data collection provide the knowledge base that directly influences all other themes and priorities in service development and delivery. Ethics remain fundamental to all themes and permeate all aspects of the entire system.

Advocacy for increased resource allocation is essential, and the international community is well placed to deliver on this agenda.

12.2. International Collaboration

International collaboration and cooperation offer great promise for critical care in low-resource settings. Telemedicine networks can connect small rural hospitals with tertiary-center intensivists for ongoing case review and clinical guidance. Volunteer physician groups assist local physicians in many countries, and their experience may provide valuable insights . Integrating emergency and critical care with other medical care and public health programs in the community, including long-term follow-up, is essential. Reconstituting services after a disaster is challenging in developing countries, where baseline emergency services are inadequate. Establishing an evidence base is prudent, but these services remain competing priorities within the healthcare system. Critical care is often deemed too costly or complicated for resource-poor settings; research emphasis should therefore be on general critical care . Quality improvement programs can optimize limited resources. Investigations into cost-effective interventions and technologies are urgently needed, with support from professional associations to develop simplified tools and guidelines for low-resource environments. Prevention should be prioritized. Multiple-casualty-categorization responders require special training, with completion documented in a professional registry accessible to nongovernmental organizations and international bodies. Competencies and crisis

standards of care remain to be developed across various specialties. Early identification of vulnerable populations and recognition of global limitations are crucial to establish appropriate response and recovery measures.

13. Future Directions

Improving the understanding of current critical supply shortages and the factors that contribute to them is a research priority. The problem may also have specific local features of importance to maintain supplies. An approach to alleviating shortages could include enhanced local production of important consumables and the establishment of working groups to analyze the problem and propose mitigation measures (A. Spencer et al., 2023). Facilities dedicated to critical care provision are poorly developed in most low-resource settings, and thought should be given to augmenting significant aspects of available infrastructure. Further research is required on the costs and benefits of dedicated critical care areas and the alternatives that might exist in the absence of these. Enhancing the capacity of the existing critical care workforce through additional training is a priority, as is community engagement allowing earlier presentation of patients. Further research should focus on how best to train a critical care workforce and to provide assistance in difficult cases, including tests of telemedicine. Knowledge regarding the burden of critical illness and the factors that influence it is incomplete, and systems for the definitions and collection of standardised, comparable data on critical illness must be established. Work is needed to understand the careful introduction of new technologies, including complex treatments, into an already limited healthcare infrastructure so as not to make changes that would be harmful to patients.

13.1. Research Needs

Critical care is the timely recognition and management of patients with, or at risk of, critical illness to reduce mortality (A. Spencer et al., 2023). Large unmet need for critical care in low-resource settings contributes to high morbidity and mortality from treatable conditions . Unmet need derives from frequent deficiencies in healthcare infrastructure, workforce, and essential equipment and consumables. Unmet need also reflects socioeconomic circumstances that prevent patients from seeking and continuing care, and lack of timely detection and management of critical illness in pre-hospital and general hospital wards. Finally, clinicians in low-resource settings must manage critically ill patients that would not usually require admission to a critical care area due to a greater burden of comorbidities and chronic conditions. At the same time, losses of healthcare workers to better-resourced healthcare systems in other countries exacerbate domestic critical care workforce deficits in some settings. Research needs therefore include better measures of unmet need and integrated approaches to its reduction; information on patient, family and healthcare worker interactions and outcomes; development of appropriate technological strategies; training and education programmes; focus on the importance of donation accompanied by advice; innovative Service Development; and improved guidelines and policy.

13.2. Technology Integration

The integration of technology into healthcare delivery is widely regarded as a strategy to improve quality and efficiency, particularly in critical care. In this regard, telemedicine may be a promising option because of the ability to integrate expertise and provide support across physical distances .

Given the uneven distribution of UK intensivists worldwide, and the rapid increase in demand for formal training programmes in critical care, the possibility of delivering training remotely through tele-intensive care may become particularly important in low-resource settings such as Myanmar. In order to build systems that maximise the benefit of telemedicine, it is crucial to understand the challenges facing critical care in the particular country, to avoid "imposing a Western model" that is unlikely to be fit for purpose in very different settings . Therefore, one primary objective of this thesis is to articulate the landscape of critical care in low-resource settings, including existing provision and the key challenges. This will also inform the development of novel, appropriate systems. Such work is particularly important, as critical care infrastructure in low-resource settings remain limited and reduces the effectiveness of any service, despite the provision of the best training. Myanmar provides a particularly suitable setting for this investigation because efforts are underway to develop a service on a national basis, and progress requires a better understanding of existing services and the challenges that prevent improvements in critical care . A second objective of the thesis is to review innovative technological solutions that have been developed in other low-resource settings, to understand their applicability to the critical care domain. In parallel, it also considers the diverse patient population served by intensive care; their characteristics provide a further test of the applicability of existing systems within the context of such resource limitations.

14. Conclusion

The pursuit of children's welfare through new knowledge and understanding inevitably leads to the discovery of new questions and problems. Effective strategies in addressing these issues may result in new challenges which, in turn, require new research initiatives for their resolution. The study of nursing research can assist in clinical or scientific problem-solving approaches to various professional situations. Every nurse should, therefore, have some knowledge regarding the research process for the identification and solution of both present and future problems in patient care. Provision of care to sick children, who are unable to speak for themselves, necessitates different approaches and the continuous formulation and testing of initiatives for their benefit.

Pediatric patients are especially vulnerable to complications or deaths related to the administration of intravenous fluids. The literature is replete with standards, guidelines, policies, and procedures on the safe administration and management of intravenous fluids, yet errors still occur in their administration. Such errors can result in complications such as circulatory accidents and fluid overload, which have overt or covert effects on the physical well-being of the patient. Adverse drug events and medication errors also contribute indirectly to such incidents. Failure to correctly prescribe the appropriate type and volume of intravenous fluids is a common factor related to deficits in nursing and healthcare delivery systems. Examples include the prescribing of the wrong fluid (e.g., dextrose), wrong volume (e.g., No maintenance or boluses of fluids), or incorrect flow rates. Because patients may be unable to communicate their needs, nurses must acquire different skills in prescribing, administering, and managing intravenous fluids to effectively meet the patient's needs. (A. Spencer et al., 2023)

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