Intensive care unit models in pandemics and beyond: Striking the balance between efficiency, ethics and equity

The COVID-19 pandemic exposed the strengths and vulnerabilities of healthcare systems worldwide, intensifying the debate over open and closed intensive care unit (ICU) models. These models have profound implications for patient outcomes, resource utilisation and system efficiency. In times of crisis, achieving a balance between high-quality care, resource optimisation and equitable access is of paramount importance. Central to this debate are ethical considerations of equity, justice and resource allocation. Ultimately, the challenge lies in determining which model most effectively treats the maximum number of patients without compromising quality of care – a decision fundamentally dictated by the availability of trained personnel, cost-effectiveness, and prioritisation of patient outcomes.

The closed ICU model, led by intensivists who oversee all aspects of care, provides centralised, expert-driven management. This model adheres to the ethical principle of utility – maximising survival outcomes by prioritising the limited resources for those most likely to benefit.

Current evidence strongly supports the superiority of closed ICUs, citing intensivist expertise, proactive infection control, and efficient resource utilisation. Sharayah *et al.*[1] reported a 19.3% reduction in central line-associated bloodstream infections along with the elimination of catheter-associated urinary tract infections and ventilator-associated pneumonias after transitioning to a closed ICU. Van der Sluijs *et al.*,[2] in a narrative review, documented a 36 - 61% cost reduction in closed ICUs. A comprehensive meta-analysis by Vahedian-Azimi *et al.*,[3] encompassing 444 042 patients, revealed significantly higher ICU mortality (relative risk (RR) 1.16; 95% confidence interval (CI) 1.07 - 1.27; $p<0.001$) and hospital mortality (RR 1.12; 95% CI 1.03 - 1.22; $p=0.010$) and longer ICU stays (standardised mean difference 0.43; 95% CI 0.01 - 0.85; $p=0.040$) in open ICUs, findings reinforced by recent systematic reviews and meta-analysis.[4,5]

The promise of improved mortality and length of stay paints a compelling picture. However, the true impact of ICU models is far from straightforward. Conflicting results, significant heterogeneity within the meta-analyses, and variability in study designs, patient populations and resources reveal just how complex this issue is. Patient and family satisfaction, long-term recovery and quality of life remain underexplored and inconclusive – important considerations when assessing overall ICU performance.

Importantly, most of the available evidence stems from the USA, where advanced technology and specialised care prevail. For low- and middle-income countries (LMICs) the relevance of this evidence is questionable, overshadowed by the harsh realities of limited infrastructure and workforce constraints.

Interestingly, closed ICUs reveal unexpected vulnerabilities during periods of extreme strain. Studies report a rise in risk-adjusted mortality in closed ICUs compared with their open counterparts,[6] and a concerning decline in adherence to prophylaxis guidelines.[7] While biases, including bias by indication, undoubtedly influence these findings, they reveal the burden of centralised responsibility and the stark reality of intensivist burnout, emphasising that even the most robust systems have breaking points.

In reality, the widespread implementation of closed ICUs is not feasible in resource-poor settings. The significant shortage of intensivists renders round-the-clock intensivist coverage an aspirational goal rather than a practical reality. The higher staffing and resource demands pose substantial financial and logistical challenges, especially for public hospitals and smaller facilities. This reliance on specialised personnel and infrastructure risks limiting access to care, potentially excluding vulnerable patients who may benefit from life-saving interventions.

Open ICUs, where general physicians manage care with *ad hoc* input from intensivists, offer flexibility and scalability, enabling hospitals to rapidly expand critical care capacity. This model prioritises equity – ensuring broader access to critical care while leveraging existing resources.

However, the decentralised structure and less standardised framework of open ICUs have inherent limitations. The absence of intensivist-led management can lead to inconsistent application of evidence-based protocols, fragmented communication and conflicting treatment decisions, particularly in complex cases. Additionally, challenges in infection control, compounded by overcrowding and infrastructural limitations, heighten the risk of nosocomial infections, a significant concern during periods of increased demand. Currently, evidence supporting open ICUs is less robust than that supporting the closed model, potentially reflecting the settings in which they are more commonly implemented. Moreover, existing literature primarily focuses on transitions from an open ICU to a closed ICU model, with little to no attention given to the reverse transition.

The retrospective study by Gwala *et al.*[8] in this issue of *AJTCCM* makes an important contribution to the limited literature from LMICs, offering timely insights into the feasibility of the open ICU model as a practical solution during periods of overwhelming demand.

To expand capacity during the COVID-19 pandemic, an open ICU, managed by base-discipline specialists with *ad hoc* intensivist support, was integrated alongside the tertiary hospital's traditional closed ICU model. Triage and bed allocation were centralised under the closed ICU team. Both units benefited from the expertise of experienced ICU nurses, a notable contrast to many settings grappling with critical shortages of such specialised personnel.

The authors compared the outcomes of 203 non-COVID patients managed under the two ICU staffing models: 77 patients in the open ICU and 126 patients in the closed ICU. The findings revealed no significant differences in key outcomes, including in-hospital mortality (16.9% in the open ICU v. 15.1% in the closed ICU; $p=0.769$), adverse event incidence (45.5% v. 38.9%; $p=0.357$), and hospital length of stay (median 4 days v. 3 days; $p=0.635$).

While the study provides much-needed perspectives for the implementation of an open ICU model, several considerations affect its generalisability. The study's focus on a younger, healthier population with low illness severity (median Acute Physiologic Assessment and

Chronic Health Evaluation (APACHE II) score 7; predicted mortality 5 - 10%) is particularly noteworthy. With a median (IQR) age of 38 (26 - 53) years, over half of the participants having no comorbidities (56%), and a substantial proportion not critically ill but admitted primarily for intensive monitoring (36%; Society of Critical Care Medicine (SCCM) score II), the findings may not readily apply to older, more complex ICU populations, particularly high-risk medical patients. This limitation is underscored by the association of advancing age and comorbidities with higher mortality in the open ICU (OR 1.034 and 4.58, respectively), absent in the closed model. Potential biases in patient allocation, an inherent challenge during crises, may explain these differences. Notably, trauma patients, typically considered high risk, were 2.4 times more likely to be admitted to the closed ICU, while a greater proportion of SCCM III patients (patients with a more guarded prognosis) were admitted to the open ICU (20.8% v. 7.1%). Although Gwala *et al.*'s study provides support for open ICUs, it serves as an important reminder to consider patient populations, illness severity and contextual factors when assessing the true impact of the ICU model in question.

Most studies have looked at the effect of medical management of open or closed ICUs. In this study, experienced ICU nurses were present in both the open and closed ICUs. The role of nurses may be an important consideration. Transition from open to closed ICU models has invariably imposed a new (intensivist-led) medical hierarchy on an established intensive care nursing system. This change in structure has usually been associated with better outcomes and increased nursing satisfaction.[9,10] Skilled nursing is one of the most important determinants of ICU outcome and may be more important than the medical input, once appropriate protocols for general ICU care and infection prevention and control have been established.

The urgent need for adaptable and flexible critical care models has never been clearer. Emerging hybrid approaches, combining the strengths of open and closed systems and tailored to the unique demands of individual settings, offer a pragmatic and balanced solution particularly suited to pandemics and beyond. However, their success hinges on strategic patient selection, and their efficacy in high-acuity, diverse populations and LMICs remains uncertain – a glaring research gap that demands immediate attention.

The COVID-19 pandemic starkly exposed the persistent inequities in access to quality critical care. This crisis calls for decisive action. Empowering healthcare providers through workforce training, contextual research, innovative technology and telemedicine will strengthen critical care delivery. Customising ICU models to meet the distinct needs of various environments offers a sustainable solution. Strengthening collaboration between physicians and intensivists, supported by standardised local protocols, is essential to reinforce critical care systems and ensure resilience. The goal is not simply to prepare ICUs for future pandemics but to address longstanding disparities that leave vulnerable communities underserved. The reward of commitment is a future where critical care is a fundamental right, not a privilege.

Usha Lalla
FCP (SA), Cert Critical Care (SA) Phys, Cert Pulmonology (SA)
Division of Pulmonology, Department of Medicine, Faculty of Medicine and Health Sciences, Stellenbosch University and Tygerberg Hospital, Cape Town, South Africa
usha@sun.ac.za

Richard Raine
MB ChB, MMed (Med), FCP (SA)
Division of Pulmonology, Department of Medicine, Faculty of Health Sciences, University of Cape Town and Groote Schuur Hospital, Cape Town, South Africa

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