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WHAT'S NEW IN INTENSIVE CARE

Frugal innovation for critical care

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Although they take care of the vast majority of critically-ill patients worldwide, intensive care units (ICUs) from low and middle income countries (LMICs) are confronted with huge challenges including medication, disposable and device shortage, in addition to human and material resource limitations. The following thoughts were driven by clinical observations during a cooperation mission in Sub-Saharan African ICUs. They aim at favoring a new approach in critical care research and innovation.

Clinical observations

The first case involved implementation of invasive monitoring of arterial pressure during shock. A young patient with septic shock from pulmonary origin, requiring mechanical ventilation and vasopressor support with norepinephrine, was equipped with an arterial radial catheter. The training focused on the use, surveillance and physiological data exploitation of such a device. Unfortunately, the patient died a few hours later due to norepinephrine shortage in the hospital and town and despite huge efforts by the ICU team. The policy of the ICU was to try promoting norepinephrine vs. dopamine in the treatment of septic shock, as per published trials and recommendations [1]. The overall superiority of norepinephrine in this setting may be questionable, given the increased mortality reported during norepinephrine shortages even in high income countries [2], and the need for a central venous catheter, which availability and surveillance may not always be straightforward.

The second observation was a very high frequency of reintubations due to mucus plugs in patients under invasive mechanical ventilation. Most patients were equipped with a heated humidifier, precisely to reduce this risk, as per the ICU policy, driven by studies suggesting heated humidifiers for optimal humidification during mechanical ventilation [3]. However, many devices were malfunctioning, due to breakdowns or mounting difficulties. The effectiveness of heated humidifiers may be judged as marginal as compared to heat and moisture exchangers in terms of clinical outcomes [4], and their use may be challenging in some tropical environments, with mostly high ambient temperature and humidity [5].

The third observation was that the only ventilator in working order in one ICU was a Servo 900C (one of the oldest ventilators), while several modern ventilators (some being similar to those used in my ICU) acquired in recent years were all rapidly out of order. The very limited life expectancy of modern ventilators in such setting has multiple causes, including the design fragilities, poor oxygen supply and power failure, and the lack of sufficient training and maintenance.

Doing more with less for more patients

Much of the current innovation in critical care is about developing standards and approaches with sophistication, complexity and high cost to address the needs of patients from the top of the economic pyramid. They are often irrelevant and can even be deleterious in resource limited or pre-ICU settings, were the majority of critically-ill patients are managed (the base of the pyramid). Recent trials reported increased mortality with aggressive fluid boluses in African children [6] and adults [7] with sepsis, possibly due to the lack of optimal ventilator support or other mechanisms. There is an urgent need to build more universal evidence involving the local financial, technological, institutional and human constraints of resource limited settings. These constraints could be transformed as an opportunity through frugal innovation.

The three major defining criteria of frugal innovation are: a substantial reduction of cost, the concentration

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on core functionalities, and optimized performance levels [8]. Distinctions between frugal innovation and conventional innovation are summarized in Table 1a [8, 9]. The frugal solution is refined to its maximum to answer precisely the need without concession on quality, but without superfluous addition. The primary aim is not reducing the cost by simply stripping off features. Instead, frugal innovation often produces high-end solutions by privileging the user need, and understanding in depth the operational environments and associated constraints. It can also favor disruptive approaches, i.e., that eventually unsettles an existing thinking, displacing established solutions.

From simple adaptation to reverse innovation

Solutions developed for a constrained environment with a frugal approach may also be particularly effective and cost competitive in high income countries, leading to the concept of reverse innovation (i.e., some insights from low-income countries might offer transferable lessons for wealthier contexts). One example is the mobile banking, initially developed in Sub-Saharan Africa and currently implemented in Europe and USA. Adopting frugality in critical care research and innovation may improve the global impact of the specialty. Disposable income influences the mortality of patients in the absence of health insurance or universal health coverage [10]. The frugal approach is also more sober, globally sustainable, and related to societal, environmental, and economic equity. It will also help fight against the unconscious bias that interferes with the interpretation of research and innovation emerging from LMICs. The urgent need for mutual learning is reinforced by growing common challenges, like the global spread of new strains of drug resistant bacteria.

Can a frugal innovation mindset be applied to critical care?

Some of the most popular examples of frugal innovation in healthcare are the MAC 400 electrocardiograph by GE Healthcare, and the Jaipur foot or knee by Dr. Sethi [11]. Most frugal innovations in healthcare are in the fields of neonatology, general practice, and orthopedics, with none attributed to critical care in a recent review [12]. However, many approaches in critical care have a frugal potential (Table 1b), that need to be expanded and refined. To practically apply the concept of frugal innovation to critical care, there are no definite blueprints to follow, but most of these solutions should be bed sided and capable of increasing the "medical autonomy" of

Table 1 Comparison of the characteristics of conventional and frugal innovation (adapted from Weyrauch and Herstatt [8] and Basu et al. [9]) (a) and examples of critical care procedures with a frugal potential (b)

Characteristics	Conventional innovation	Frugal innovation
(a) Characteristics of conventional and frugal innovation		
Driver	What would be nice to have	What do they need
Process	Top–down	Bottom–up
Constraints	Conceived as barriers	Conceived as opportunities
Core capabilities	Desirability and design	Functionality and focus on essential, high value and quality, rugged, adaptable, simple, user-friendly and easy to use
Cost/resources	Exploiting all potentially available resources	Accessible and affordable, minimising the use of material and financial resources, sustainable
Location	High income settings	All settings (universally accessible)
Setting	**Procedure**	**Possible frugal development**
(b) Some examples of critical care procedures with a frugal potential		
Sepsis	Antimicrobial stewardship	To develop affordable, simple and efficient testing for resistant strains, if possible on direct examination and at bedside, using for example the β-LACTA™ test technology [13]
Hemodynamics	Skin-derived tissue perfusion indices [14]	To improve standardization and reproducibility of these skin-derived techniques
Monitoring	Critical care ultrasound, especially with miniaturized devices [15], for bedside hemodynamic assessment, lung imaging, and catheter placement…	To improve robustness and miniaturization of devices without concession of pertinent modes for hemodynamics (e.g., pulsed Doppler) and pertinent usages. To widely implement (including by nurses) multipurpose ultrasound-driven protocols to improve clinical outcomes

the intensivist and the ability to manage the critically-ill independently from a constrained environment.

Considering the issue of ventilator support for example, the device should be focused only on the delivery of a safe ventilator support. Available ventilatory modes should be selected based only on their clinical pertinence and need (e.g., high flow-oxygen, continuous positive airway pressure, airway volume or pressure assist), while discarding superfluous or redundant options. The robustness is an essential characteristic, with an internal conception compatible with extreme temperatures, dust, unstable power sources and electric blackout. The device should be highly functional, user friendly, and easy to use (by intensivists, nurses, and even family members if needed, given the scarcity of healthcare professionals in some settings). The device should of course be affordable, as well as its consumables (which should be non-captive and if possible, re-usable). The monitoring should also be focused only on the need, i.e., variables useful to check effectiveness and safety of ventilatory support. A specific training programme should be integrated to the solution, because the need to be addressed is the ventilation, not the ventilator. Recent advances in learning and communication technologies (e.g., online courses and simulation) should be exploited to deliver such training easily and broadly. The maintenance should be as easy as possible, and feasible at least in part by the end-user, especially for crucial elements like the battery, the filter or even the turbine. We hope future collaboration with health industries will allow the emergence of such solutions, which may be pertinent, both from a medical and an industrial point of view.

Conclusion

In conclusion, a frugal approach may allow performing better care with fewer resources for more critically-ill patients. Frugality could be introduced as a quality criteria in future innovations and research in critical care medicine.

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Compliance with ethical standards

Conflicts of interest

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