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The Future ICU

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The Intelligent Intensive Care Unit: Integrating Care, Research and Education

Integration of care, research and education in the intelligent intensive care unit.

Patients admitted to the intensive care unit suffer from a variety of symptoms, pathologies, and comorbidities and are at risk of many adverse outcomes. Healthcare and technology for this vulnerable, heterogeneous patient group have immensely developed over the past decades, but even though mortality rates have fallen, they are still high. Caregivers should be informed about variables important for decision making as soon as possible after admission. Education on how to obtain and value important variables, how to use these variables for innovative research, and how to implement new knowledge into daily practice are upcoming challenges for the intelligent ICU.

Identification of critical elements of future research exists. The heterogeneous group of patients requires research in large sample sizes. Additionally, multicentre approaches become more standard as patient populations will differ between hospitals and countries, single-centre studies impair generalisability and external validation. Current research efforts do not yet cover the complexity of research in the ICU. For example, the extraction of retrospective data from Electronic Health Records is currently labourious, error-prone, and hampered by the official registration of data as plain text rather than discrete values. Also, datasets often are not interchangeable between hospitals and countries, and there is a lack of the practical application of guidelines for standardised data collection. One of the challenges is to reduce high variability and improve the quality of data. Collaboration between researchers is mandatory.

> "medical innovation could assist in achieving more efficient care, fewer and shorter hospital admissions, reduced costs and an optimal distribution of limited resources in health care"

Improving research is part of an ongoing strategy. The first step is to start at the inclusion of patients, preferably at the moment the patient enters the ICU. When assessing each patient in a structured manner, we can potentially decrease some heterogeneity by characterising specific processes. Improving characterisation could then aid in identifying which patients are eligible for specific trials and which are not, short after ICU admission. Currently, randomisation can be a challenging process in the ICU as critically ill patients are not a homogenous group, and two patients with the same disease are still very different and may respond differently to treatment and have various outcomes. An increasing number of trials correct for this heterogeneity, but this remains error-prone and does not appreciate the complexity of the patient population. The first step should be to investigate and characterise our patients during the early phase after admission to the ICU.

To look at patients shortly after ICU admission in a structured way is trainable. Obtaining simple variables according to a predefined protocol may better inform caregivers in their clinical decision making and will be useful for randomisation of

this heterogeneous group of patients. While research improves our understanding of complex diseases, the type and nature of the variables we should look at can evolve. By training caregivers in a structured approach, potentially with the use of newly developed technological tools, they can improve the identification of their patient in an earlier phase. When this becomes standard practice, the implementation of newly discovered characteristics or sub-phenotypes of clinical syndromes is feasible. For example, one study showed that a systematic application of a point-of-care ultrasound driven protocol shortly after ICU admission could guide diagnostic and therapeutic decisions in critically ill patients (Pontet et al. 2019). Applying their protocol resulted in decreased utilisation of conventional diagnostic imaging resources and time of mechanical ventilation and facilitated an acute intravenous fluid administration in critically ill patients during the first week of ICU hospitalisation.

Unfortunately, both development and implementation of new technological tools, such as ultrasonography, are often troubled and delayed by the lack of substantial evidence and proper research. Technological innovations can directly benefit critically ill patients by promoting a shift towards the use of more validated non-invasive techniques which may decrease the risk of complications typically associated with invasive techniques and improve patient comfort. As patients may be(come) haemodynamically unstable, high-quality monitoring of vital signs is needed but optimally while using low-risk devices to avoid any additional harm. At an organisational level, medical innovation could assist in achieving more efficient care, fewer and shorter hospital admissions, reduced costs and an optimal distribution of limited resources in health care.

New non-invasive devices are developed to streamline healthcare operations, lower costs, and enhance the quality of care. However, it is still unclear whether the currently used non-invasive measurement techniques measure is as reliable and precise as invasive measurement techniques in critically ill patients. Before increasing the use of non-invasive measurement techniques, or even develop new ones, it is essential to test these devices and compare the measurements to the clinical reference techniques. Fast yet accurate testing and validation of new non-invasive devices could aid in making more use of newly developed technologies in healthcare. Unfortunately, the road to appropriate implementation of these devices is fierce, and many fail to fulfil their purpose.

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Besides the direct benefit to a patient's health, accurate measuring of vital signs in further efforts could improve care for the critically ill. As algorithms and prediction models are evolving, implementing algorithms and models becomes likely in the foreseeable future. Current examples of commonly used ICU general risk prognostications scores are the Acute Physiology and Chronic Health Evaluation (APACHE IV), the Simplified Acute Physiology Score (SAPS III), and Mortality Probability Model (MPM III). These prognostic models have been extensively studied and validated but show variable results, and thus are still not commonly used in daily practice (Strand and Flaatten 2008; Salluh and Soares 2014). The first step into creating accurate models, however, with simple statistics or even machine learning, is to gather reliable measurements, and thus, data. Therefore, before we may develop reliable estimations of prognosis to inform caregivers adequately, patients, their families, and future research, values of vital signs used in these existing models must be reliable, available as soon as possible, easy to update and be informative for both short-term mortality and longer-term patient-important outcomes.

Besides simple data based on clinical examination and monitoring, prognoses made by physicians and nurses can be valuable for outcome predictions. Several studies have evaluated the predictive value of caregivers' estimations on clinical outcomes of critically ill patients (Scholz et al. 2004; Sinuff et al. 2006; Detsky et al. 2017). Outcome predictions are of great importance for treatment decisions in the management of critically ill patients and prognostic models based on clinical examination, and caregiver estimations might have an added value to existing scores. Predicting outcome in the first hours after ICU admission, however, remains a challenge.

The Simple Observational Critical Care Studies (SOCCS) was designed to compare the prognostic value of the students, nurses, and physicians' educated guess with currently available risk scores to predict short term mortality in the ICU (NCT03553069). Within this study, teamwork is very important; a team of over thirty students is available 24/7 to include all acutely admitted patients within the first 3 hours after admission. At admission of the patient to the ICU, the physicians, nurses and students are asked to estimate in-hospital survival based on gut feeling. The estimation, the risk assessment using, e.g. SAPS and SOFA, and the actual outcome, are collected.

We created the possibility to compare the performance of all models in our population. We will identify models that are useful to predict the severity of the disease in our setting.

Furthermore, we show that using machine learning predictions made by caregivers can be predicted themselves (Kaufmann et al. 2019). Predicting predictions, either right or wrong, for the base for education on how to value variables more appropriate and in addition to that improve forecasting in individual cases. A next step might be to establish a collaboration between caregivers and machines to use the intelligence of both for further improvement. To get data for this process, implementing a systematic observational data collection is the first step towards making data-driven research possible. With a multicentre, multinational database for each setting, the best performing models can be identified, implemented, and over time, updated. The second step towards improving the use of technological innovations in the future ICU is a collaboration between multiple centres. (Inter) National collaboration could result in high-quality studies with large sample sizes and possibilities for external validation. A research platform that allows for standardised, scalable and reproducible observational research could improve the general quality of scientific research, and likely also the quality of healthcare in critically ill patients. Technological innovations will be necessary to support this infrastructure, allowing for simplified data exchange between systems, increasing interoperability and optimising data availability. Reliable, clean and complete database of reliable variables of patients admitted to the ICU should be available for research while complying with privacy and data storage regulations. Eventually, this will allow for validation of non-invasive devices and building accurate prognostic models, which both aid in clinical decision-making and quality of patient care.

In conclusion, innovation is the key to improve healthcare through an intelligent ICU. Physicians and nurses will go back to the bedside and investigate and characterise our patients in an early phase after admission to the ICU. We will train our caregivers to use a structured approach with the use of newly developed tools to improve the identification of patients in an earlier phase. To make more use of innovations and to eventually improve the quality of care in the ICU, teamwork and collaboration are necessary. Multiple centres will work together to conduct standardised, multicentre scalable and reproducible observational research in ICUs. High-quality research will directly benefit healthcare in critically ill patients, but also patients in general, and likely also at the level of organisations and scientific research. ■

Key Points

- Innovation is the key to improve healthcare through an intelligent intensive care unit.
- Physicians and nurses have to go back to the bedside and investigate and characterise our patients in an early phase after admission using a structured approach.
- Upcoming challenges are: education on how to obtain and use important variables for innovative research and how to implement new knowledge into daily practice.
- Teamwork and collaboration between researchers are mandatory.

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