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Technology innovations in delivering accurate nutrition

Preventing malnutrition and enforcing nutritional guidelines

An overview of the key obstacles for the enforcement of nutritional guidelines and innovative approaches that can be used to overcome these obstacles.

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Recent studies suggest that nutritional guidelines across the majority of intensive care units (ICUs) are not being implemented (Bendavid et al. 2017; Heyland et al. 2003). Lack of knowledge, no technology to support medical staff, and general noncompliance with nutritional guidelines result in higher mortality and infection complications. This review highlights the main obstacles for the enforcement of the guidelines and recommends several innovative technology approaches to overcome these obstacles, some that should be investigated and others that should be developed.

Immediate, continuous and feeding tube placement independent of x-ray for early enteral nutrition, reduced radiation and position verification

Naso-orogastric tube is recommended (Singer et al. 2018) in the majority of the cases as it is simple to be introduced and simple to be checked by x-ray. This easy access allows enteral feeding to start relatively early and in a simple way. However, enteral feeding using gastric tube access can be associated with large gastric residual volume that may minimise the use of this route (Singer et al. 2018). An alternative option is to use the duodenal or jejunal access. But this access requires the help of endoscopy or fluoroscopy or the ability to introduce these tubes at the bedside using well-trained techniques. All these accesses may increase the risk of gastrointestinal complications and lead to a loss of time to start enteral feeding and reach the target nutrition. Even if gastric feeding is chosen, delayed position verification via x-ray, due to x-ray technician priorities, may result in delayed feeding.

Not being able to perform continuous verification makes this technique outdated because the tube may migrate to the oesophagus during the feeding process and the patients may suffer from aspiration until the nurse/caregiver repositions the tube.

> "providing higher calories target than is needed has been found to be associated with increased mortality"

New technologies using tubes with end tipped video camera, guide wires or anti-retroperistaltism have been introduced with limited success. Continuous position verification technologies should be explored. The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines (Singer et al. 2018) recommend the use of post-pyloric access in case of gastric feeding intolerance. The cost-benefit of these techniques has to be demonstrated.

Indirect Calorimeter IC/REE device for calculating the patient's actual energy expenditure, initially and potentially continuously

One of the main pitfalls is the common use of predictive equations like Harris-Benedict equations for targeting energy prescription in critical illness. The equations have been demonstrated by many (Zusman et al. 2018; Tatucu-Babet et al. 2015) to be inaccurate in more than 50% of the cases, leading to under or over nutrition. In case of too low a target, patients will be underfed and, since the process is progressively increasing the rate of administration, calorie balance will reach large negative values that are associated with increased morbidity (Dvir et al. 2005).

Providing higher calories target than is needed has been found to be associated with increased mortality (Zusman et al. 2016), resulting in recommendations by ESPEN to measure energy expenditure in a rested condition [REE] (Singer et al. 2018). New easy-to-use devices have been developed to help physicians determine energy needs at the bedside (Oshima et al. 2017). These

devices measure the actual resting energy expenditure related to the specific patient condition. Using REE continuously may also allow monitoring of the changes in a patient's energy consumption and amending the feeding plan accordingly to these changes. Further studies are required to confirm these findings.

Replacing the periodic total gastric evacuation with triggered reflux event

The gastric administration of enteral feeding is associated with more vomiting and reflux than parenteral nutrition (Reignier et al. 2018). The reflux and regurgitation are a factor for increasing the risks of ventilator-associated pneumonia (VAP), and there is a constant conflict between increasing feeding rate for reaching the nutritional goal and reducing feeding rate for decreasing aspiration. Therefore, clinicians are cautious in the progression of the rate of administration of enteral feeding in order to decrease the risks of reflux and vomiting and not increase the risks of VAP. Elevating the head of the bed to a half sitting position is the only demonstrated technique that reduces the incidence of VAP. The assessment of gastric function using gastric residual volume (GRV) to test periodic aspiration is clinically used, but is not useful in monitoring enteral nutrition administration (Reignier et al. 2013). For an effective result of gastric evacuation, gastric residues should be released when reflux occurs, and not in an arbitrary and pre-determined (once every 4 hours) timeframe. The use of new feeding tubes with real-time reflux detection should be examined.

Continuously calculating nutritional losses and providing feeding compensation in real time

As stated previously, the compliance to guidelines as well as to prescription rarely achieves the nutritional goal. Numerous reasons may explain this poor adherence, but the need to give the prescribed dose of enteral feeding is not perceived as the need to administer an adequate and timely antibiotic prescription. An assessment of the patient's delivered feeding efficiency should be monitored by technology methods, not manually by the nurse. Elements that should be continuously calculated are:

1. Time lost by stopping feeding, for example, related to surgical procedure, CT or MRI tests.
2. Being able to calculate and continuously compensate for all nutritional losses.

Both compensation elements should be automatically managed by the feeding pump and should be the new standard technology used in nutritional care. This would also free nurses' time.

Enforcing methodologies and guidelines through a "strict" flow and interactive help guides in the feeding platform

As mentioned before, intensivists should have more knowledge about the consequences of over- and underfeeding. A technology device assisting the medical staff and supporting adherence to the guidelines could be an important part of the decision support system. Relevant apps should be developed to support the process.

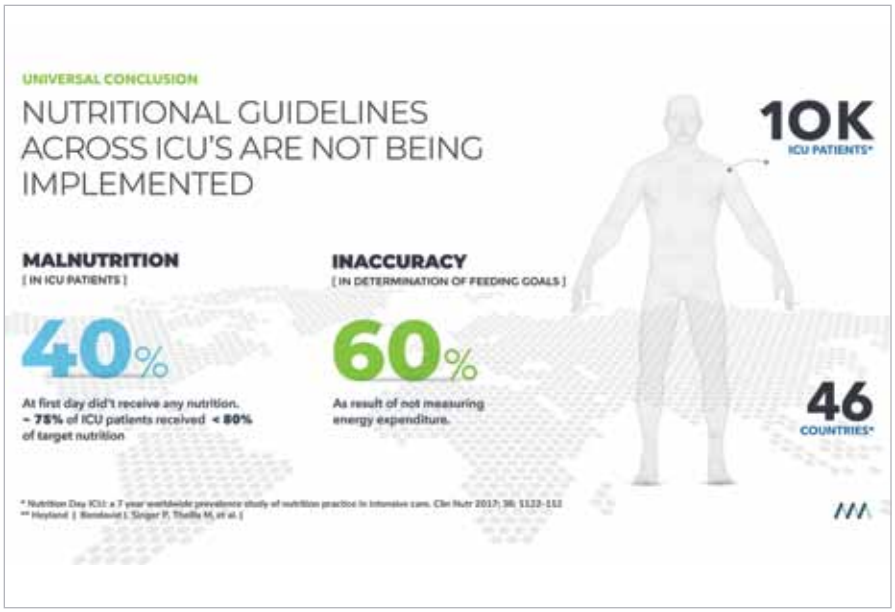
Per patient auto-calculation of 100% caloric target and the relative parenteral supplement suggestion for reaching nutritional goal

Industry products contain carbohydrates, fat, and protein in a fixed ratio. When measured, the patient's energy expenditure will never be exactly as the specific ratio of feeding formulas. In addition, evaluating datasheets of all feeding formulas in-stock to determine which one fits best to the specific patient and what are the supplement that should be added accordingly is a challenge. Classical formulas contain more carbohydrates (55%), less fat (30%) and protein (15%). If energy is targeted, as in most cases, the feed content may reach the energy target but not the protein one. Therefore, the protein deficit needs to be calculated and accounted for. If a rate of a specific product is raised to increase protein administration, according to the guidelines, a patient may be overfed in his caloric target (caloric target, per the

Reasons for malnutrition and inaccuracy of feeding

The top ten reasons why malnutrition and inaccuracy of feeding occur today include:

1. Feeding tube misplacement and delayed feeding as a result
2. Inadequacy of predictive equations to determine target energy plans
3. Routine and manual gastric residual volume evaluation to prevent reflux and aspirations
4. No feeding compensation if nutrition stopped or drained for evaluation
5. Lack of knowledge and "How to..." guidelines regarding over/under feeding and protein deficit consequences
6. No personalised feeding formula solutions
7. Massive negative energy balance post discharge and no follow-up capabilities
8. Intra-abdominal pressure not monitored
9. No nutrition audits are being performed except Nutrition Day ICU
10. Not enough tools created for metabolomics and proteomics assessment



guidelines are 30%, 50%, 70% in the first 3 days) and may have an increase in complications. Seeking 70-100% of the caloric target may be preferred (Zusman et al. 2016).

Personalised nutrition is very difficult to achieve, and only recently the industry has started to propose more balanced products to answer specific clinical requirements. Moreover, the standard of care suggests using enteral nutrition if gastric tolerance allows it. Some studies (Casaer et al. 2011) have been understood in such a way that parenteral nutrition per se may be harmful and should not be prescribed in critically ill patients or only late in the clinical course. This is despite the fact that many recent papers (Harvey et al. 2014) have shown the safety of parenteral nutrition. This reluctance to prescribe parenteral nutrition in cases of enteral nutrition failure is leading to negative caloric and nitrogen balance and may lead to impaired clinical outcomes (Dvir et al. 2005). Supplemental parenteral nutrition should be considered in any case of risk of undernutrition if enteral feeding does not reach the target after 3-7 days (Singer et al. 2018).

The optimal combination of enteral and parenteral should be personalised for the patient by technology means that can dynamically fit the formulas to the patient's measured energy needs.

> **"reluctance to prescribe parenteral nutrition in cases of enteral nutrition failure is leading to negative caloric and nitrogen balance and may lead to impaired clinical outcomes"**

Artificial intelligence (AI)-powered algorithms and predictive models for managing the cumulative energy balance and the nutritional strategy

Most of the ICUs are not equipped with computerised information systems allowing calculation of daily and cumulative energy balance. This value may be missed if not evaluated daily, and the importance of keeping tight calorie balance may be disregarded. The cumulative negative energy balance may reach -10,000 kcal, thereby increasing the risks of morbidity and mortality (Dvir et al. 2005). Another substantial risk is the rehabilitation of a patient post-discharge that can be prolonged substantially (Wischmeyer and San-Millan 2015). The next generation of feeding technology will need to explore the benefits of continuous energy expenditure and use AI and prediction algorithms to handle caloric and protein deficit. Communication between ICU and post-ICU discharge units to understand nutrition regime and predictive deficit, and an app to help the patient to recover after post-hospital discharge, is needed. Using the knowledge acquired in the analysis of hospital food left uneaten by patients to evaluate the energy, protein and vitamins deficits, a similar approach could overcome the deficits in the post ICU period. Similar tools, if implemented in the critical stage, could help to ensure that a patient's nutritional plan and goals are constantly measured, monitored and achieved. Wearable data could be integrated with EHR data, including data from sensors continuously measuring physical activity and glucose level.

Continuous monitoring of intra-abdominal pressure

ESPEN (Singer et al. 2018) and WSACS- the Abdominal Compartment Society (Cheatham et al. 2009) recommend monitoring intra-abdominal pressure in patients with clinical conditions such as pancreatitis, retroperitoneal haematoma, traumatic surgery associated with severe bowel oedema, ascites, etc. (Singer et al. 2018). In the case of increased pressure, enteral feeding should be decreased, and even stopped in case of abdominal compartment syndrome. These conditions impair the administration of adequate medical nutrition therapy if parenteral nutrition is not prescribed. It would be highly desirable to have tools to continuously monitor abdominal pressure that create the necessary alerts and prediction towards Intra-Abdominal Hypertension (IAH) and Abdominal Compartment Syndrome (ACS), so that the medical staff can act accordingly.

A nutrition audit

Malnutrition assessment has not been validated in the ICU beside SGA (Detsky et al. 1984). A new malnutrition assessment based on ESPEN suggestions is now evaluated (Cederholm 2018). Because of this lack of tools, malnutrition or overfeeding is not recognised in critically ill patients, and malnutrition is not mentioned in most

of the charts. Most ICUs do not perform nutrition audits except the Nutrition Day ICU (Bendavid et al. 2017), which is only done once a year. Unified cloud-based assessment platforms will enable continuous audits on a broader scale, with analytic tools that will allow clinical staff to amend their performance.

Big Data analytics on metabolomics and proteomics.

The growing fields of metabolomics and proteomics hold the potential to assess nutritional status, set appropriate adjustments of the nutrient mix, and monitor progress through the varied stages of acute illness. Recent evidence indicates that such enhanced precision may be profitably integrated into severity of illness indexes such as the sequential organ failure assessment score (SOFA score), cluster analyses, and inflammatory cytokine marker profiles to prognosticate with enhanced proficiency the outcome of life-threatening sepsis (Wischmeyer 2017). 'Big Data' analytics of relevant populations, and perhaps of the myriad points of physiologic data and laboratory variables that pertain to the individual, has only begun to show their decision support potential (Marini et al. 2019).

In summary, to improve patient safety, reduce mortality, and decrease complications and length of stay in the ICU, technology should be able to assist with the following:

1. Optimal patient feeding through a combination of real-time reflux detection and prevention.
2. Energy expenditure measurement and continuous personalised feeding formula selection.
3. Continuous monitoring of the enteral feeding delivery.
4. Calculations and continuous monitoring of supplement nutrition.
5. Automated information flow between units.

Conclusion

Medical nutrition therapy is suffering from a lack of technological support compared to respiratory or circulatory therapy. Better evaluation of energy needs, better assessment of gastrointestinal failure and of tolerance to enteral feeding, and better prevention of the complications related to this route may tremendously improve the safety and efficiency of this therapy. Technology-enabled solutions may be the answer by developing better tools, giving the physician and the nurse the ability to comply with the guidelines. Compliance with the guidelines will result in better patient safety, lower mortality, fewer complications, reduced length of stay in the ICU, and reduced overall healthcare costs. ■

Key points

- Nutritional guidelines across the majority of intensive care units (ICUs) are not being implemented
- Medical nutrition therapy is suffering from a lack of technological support compared to respiratory or circulatory therapy
- Continuous position verification technologies should be explored
- Providing higher calories above needed target has been found to be associated with increased mortality
- The use of new feeding tubes with real-time reflux detection should be examined
- An assessment of the patient's delivered feeding efficiency should be monitored by technology methods

Abbreviations

AI	Artificial intelligence
ACS	Abdominal Compartment Syndrome
EHR	Electronic Health Record
ESPEN	European Society for Clinical Nutrition and Metabolism
GRV	Gastric residual volume
IAH	Intra-Abdominal Hypertension
ICU	Intensive care units
REE	Rested energy expenditure
SOFA	Sequential organ failure assessment
VAP	Ventilator-associated pneumonia
WSACS	World Society of Abdominal Compartment Syndrome

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