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Recovery

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Continuing rehabilitation after intensive care unit discharge

Opportunities for technology and innovation

This article discusses technological innovations that promote survival and enhance recovery, starting within the ICU with developments in ventilation, sedation, early mobility and ICU design. Post-ICU, the establishment of follow-up services is discussed, as are initiatives for sharing patient information to achieve better continuity of care and the novel concept of teleclinics. Specific issues after ICU with sexual function and driving are also addressed. New developments for the future are also outlined.

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The Kings Fund in the UK published a seminal report in 1989 about intensive care unit (ICU) services, acknowledging for the first time: "There is more to life than measuring death" (Kings Fund 1989). Since then morbidity after ICU has been viewed as an outcome, and much more has been learnt about what is now known as post-intensive care syndrome (PICS) (Needham et al. 2012), a clinical syndrome that encompasses a constellation of physical symptoms (e.g. muscle weakness, fatigue, reduced mobility), cognitive dysfunction (e.g. impaired memory, reduced concentration) and psychological symptoms (e.g. depression, anxiety, sleep disturbance). Such issues are commonplace; for example, a systematic review found that ICU-acquired weakness affected 32% of those ventilated for 7 days (Appleton et al. 2015), whilst ICU survivors report lower physical health-related quality of life than the general population (Cuthbertson et al. 2013). Similarly, 20% of ARDS patients show signs of impaired cognition six years after discharge (Harvey et al. 2016). Furthermore, a meta-analysis of post-traumatic stress disorder (PTSD) in ICU survivors showed a rate of 20% at 1 year post-discharge (Parker et al. 2015), and 44% of those discharged were found to be anxious and depressed (Griffiths et al. 2013). This syndrome can extend to families of those who have been in ICU, who also exhibit signs of psychological distress (PICS Family; PICS-F) (Davidson et al. 2012) and the effects can last for years, especially if the ICU survivor has a poor quality of life (Mikkelsen et al. 2017). The consequences of both PICS and PICS-F extend beyond the realms of immediate physical and mental health to economic and social dysfunction, as those affected struggle to return to work or education, or stop work to care for their loved one (Griffiths et al. 2013).

All this evidence demonstrates that the road to a full recovery and return of baseline function following critical illness and ICU admission is long, and is filled with challenges. Innovation in the implementation of systems and the development of new technology can help optimise patient outcomes and experiences. The changes that affect our cohort of patients are occurring simultaneously within and outside the ICU.

Innovation and technology within the ICU

Recovery from ICU begins in ICU. Guidance from the ICU Delirium and Cognitive Impairment Study Group (2017) and by Barr et al. (2013) outlines the importance of effective management of pain, agitation and delirium. By achieving this, oversedation can be avoided, which subsequently reduces ICU-acquired delirium and weakness (Vasilevskis et al. 2010). The ABCDEF bundle has been developed to help guide healthcare professionals; it consists of **A**ssessing/managing pain, spontaneous awakening/**B**reathing trials (sedation holds), **C**hoice of sedation, assessing/managing **D**elirium, **E**arly mobility/**E**xercise, and **F**amily involvement (ICU Delirium and Cognitive Impairment Study Group 2017). Balas et al. (2014) measured the impact of this bundle and found ventilation duration was reduced by three days and delirium duration was reduced by one day.

Weaning

Advances in ICU equipment and pharmacology have also changed practice. For example, new closed loop ventilator systems with automatic weaning (e.g. IntelliVent® [Hamilton Medical], SmartCare™ [Draeger Medical]) also purport to reduce total ventilator days. A Cochrane review showed SmartCare™ decreased weaning time and reduced length of ICU stay in critically ill adults (Burns et al. 2014). Similarly, when considering sedation Shehabi et al. (2012) found that deep sedation in the first 48 hours of admission was related to number of ventilator days (i.e. deeper initial sedation led to delayed extubation). Alternative sedatives (e.g. dexmedetomidine) have been shown to reduce ventilator days when compared to traditional sedatives (Riker et al. 2009) and are increasingly being used in clinical practice.

Communication

One of the key frustrations of ICU patients is the inability to communicate effectively with staff and family members, and advances in technology have real potential to make this experience smoother. For example, devices that allow patients to select pictures that then vocalise certain phrases, or eye-tracking devices that allow patients to control a mouse cursor can allow quite unwell patients to communicate (ten Hoorn et al. 2016). In a small study, the ability to communicate was shown to reduce dropout depression and anxiety (Maringelli et al. 2013). However, there is a need to make this technology personal to the individual; Stayt et al. (2015) identified the risk that novel technology could potentially be dehumanising and divert attention from the individual's psychosocial needs. Clearly a balance needs to be achieved but there are significant gains that could be made.

Early mobilisation

Early mobilisation is becoming an important standard of care and is often matched with alternative strategies to maintain muscle strength and function. A systematic review by Adler and Malone (2012) found early mobilisation to be safe and provide a significant benefit in terms of functional outcomes. Similarly, early physiotherapy was found to reduce the duration of ventilation and delirium, and led to better functional outcomes on hospital discharge (Schweickert et al. 2009). Scores in the the Chelsea Critical Care Physical Assessment (CPAx) tool, used to measure physical morbidity in ICU, have a clear association with discharge destination from hospital (Corner et al. 2014). This is significant in planning rehabilitation after critical illness.

A universal ICU recovery programme (akin to cardiac rehabilitation following myocardial infarction) is lacking

Motor-assisted movement therapy devices (e.g. MOTOmed® [Medimotion, Pencader, UK]) offer a range of exercises that may be appropriate even for sedated patients, helping to maintain muscle strength and function (Needham et al. 2009). Such devices have demonstrated improved six-minute walk distance and self-reported physical function by hospital discharge, though this could be ascribed to the longer physiotherapy sessions as opposed to the technology itself (Needham et al. 2009). The Mollii suit™ (in development by Inerventions, Danderyd, Sweden) is designed to help spasticity using transcutaneous electrical nerve stimulation (TENS) technology to develop muscle movement, control and tone. There is minimal peer-reviewed evidence to support benefit of this system over existing treatments but the UK's National Institute for Health and Care Excellence (NICE) has issued an innovation briefing (NICE 2017) and is monitoring its development. It is unclear whether this technology is suitable for post-ICU patients, though if benefit is demonstrated in other populations then further research into the post-ICU cohort may be warranted.

Environment

Technology may also play a part in the design of new ICU environments. For example, cycled lighting systems that aim to minimise disruption to natural circadian rhythms are associated with a more positive patient experience (Engwall et al. 2015), though objective assessment of benefit is less evident (Engwall et al. 2017). Smart alarms, that combine multiple parameters to reduce false alarms (da Silva et al. 2012), and sound-absorbing materials (Johansson et al. 2016) have both been proposed. The Helen Hamlyn Centre for Design at the Royal College of Art is developing Senso, an app that aids orientation to time and helps to create routines for patients, for example by providing relaxing music and images at sleep time with the aim of promoting sleep and reducing delirium/distress, which in turn has the potential to improve psychological outcome (Meldaikyte, pers. comm. 2016). All of these features may make the ICU environment less alien.

Innovation and technology after the ICU

We are increasingly aware of the long-term consequences of critical illness and ICU admission. To this effect ICU teams are increasingly involved in the long-term care of patients following ICU and hospital discharge. Although ICU follow-up clinics have existed in the UK since the early 1990s their implementation is variable; in 2006 only 30% of units (Griffiths et al. 2006a) had a follow up service, whilst in 2014 only 27.3% of ICUs offered a clinic-based follow-up at 2-3 months post-discharge (Connolly et al. 2014). These can often be used to identify patient/familial issues and coordinate their ongoing medical care and rehabilitation (de la Cerda 2013).

The Royal Brompton & Harefield NHS Foundation Trust has developed a novel web-based pathway called *Hospital to Home*, which is used for all adult patients who have received ECMO (**hospitaltohome.nhs.uk/adult**). This platform allows sharing of patient information across different teams on different sites, from the base time at the Royal Brompton to the repatriation team to the outpatient follow-up teams. It goes some way to ensuring better continuity of care for these complex patients, and there are indications that this joined-up care can also lead to significant resource savings (Langley et al. 2017).

Former ICU patients may have specific physical health consequences of their ICU admission. For example, in patients who received a tracheostomy (up to 24% of those requiring mechanical ventilation; Raimondi et al. 2017), tracheal stenosis is a recognised complication. Advances in MRI/CT technology can be used to identify and follow up such patients, though information on morbidity from this is lacking (Veenith et al. 2008). Similarly, sexual dysfunction is common in post-ICU patients, with up to 45% of former patients reporting problems (Quinlan et al. 2001). Erectile dysfunction is an area of active technological development, with innovation in external penile support devices, vibrators, low-intensity extracorporeal shockwave treatments and impulse magnetic field therapies (Stein et al. 2014). Both men and women may also require referral for psychosexual therapy.

A universal ICU recovery programme (akin to cardiac rehabilitation following myocardial infarction) is lacking. However, some attempts have been made to investigate possible beneficial components. Jackson et al. (2012) performed a pilot study of a programme comprising both cognitive and physical rehabilitation lasting 12 weeks. New technologies (e.g. video calls) formed a central component alongside established follow-up practices such as home visits. Furthermore, they used videos of patients doing physical and functional activities in their homes and "motivational" phone calls. The authors believe that this was the first initiative using such technology with ICU survivors, and noted the benefits of being able to reach those who may be too debilitated to reach hospital, and those who may live too remotely to return to the hospital. This allowed access to specialists that these individuals may not otherwise have had, as well as potentially reducing both direct costs (e.g. costs of hospital appointments, hospital transport) and indirect costs (by reducing the socioeconomic burden of health). The researchers concluded planned physical and mental activities are potentially beneficial in this population and need further research.

The ability to drive is often an important target for patients in their recovery. However, it is also an extremely useful marker of progress for healthcare professionals, as it requires simultaneous and interdependent physical and cognitive functioning. Advances in technology are making adaptions easier and cheaper in normal vehicles allowing patients to overcome specific physical difficulties. Programmes like the Motability Scheme (**motability.co.uk**) allow patients access to facilities to develop their own independence. This has been shown to improve independence and confidence (Meyer & Waldmann 2015).

Innovation in change

The above demonstrates numerous examples of how innovation and technology have influenced specific components of the ICU recovery pathway. However, the processes by which we identify and deliver changes themselves are also evolving and improving over time. For example, Locock et al. (2014) demonstrated how the Accelerated Experience Based Co-Design (AECBD) approach, which involves using patient experience narratives (often in the form of videos) to facilitate multilateral discussions between patients and healthcare professions, can be used to drive patient-centred service improvements. They demonstrated that the process is welcomed by both staff and patients, and the co-design approach puts patients at the heart of service development. We have used a similar strategy in our own ICU on several occasions; for example, our "Voiceless" project identified patient frustrations with their difficulties in communication, and has led to the development of materials and leaflets that form a starting point in educating staff, patients and families and ultimately ensuring more effective interaction.

Conclusion

As we have seen, there are many opportunities for innovation and the introduction of new technology throughout the healthcare journey for the ICU patient. These may address physical, psychological and cognitive factors relating to individual patients and their families, or may be used to implement wider service level improvements. Nevertheless, as new technology is developed, new opportunities for improvement arise. There is plenty of scope for continued improvement in the future.

Conflict of interest

Sara Evans has attended study days paid for by Orion Pharma (dexmedetomidine). Dhaneesha Navin Sannasgala Senaratne declares that he has no conflict of interest. Carl Waldmann has received travel expenses and an honorarium from Orion Pharma to chair a study day. ■

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