Combining Clinical Practices and Technology in Critical Care Medicine

1

Younsuck Koh

1.1 Introduction

The intensive care unit (ICU) is a place in which various advanced medical technologies are gathered for the monitoring and management of severely ill patients. Medical technology now permits a more precise and timely diagnosis and treatment than when the modern era of intensive care began. These days, we could not contemplate an ICU without the relevant medical tools and equipment. As intensive care becomes more complicated due to the increased intricacies of critical illnesses, the relevant state-of-the-art medical technologies have also been evolving to meet the requirements of intensive care providers and patients.

Medical technologies have now expanded beyond the ICU. Clinical simulation systems provide safe clinical skill training opportunities so that patients need not be subjected the training needs of resident physicians on rotation in an ICU. Moreover, with the integration of current digital technologies into medicine, traditional medical practices have been changing more than expected.

However, the latest medical technologies are frequently expensive, and the clinical outcomes do not always justify the expense. In this regard, deciding on the technologies that should be adopted and determining how to integrate them into clinical practice for appropriate critical care has become an important issue. Another concern is that a high dependence on technology will lead to deterioration in clinical reasoning abilities and the skill levels of critical care trainees. Hence, the debate on the validity and cost-effectiveness of specific new technologies

Y. Koh (✉)
Department of Pulmonary and Critical Care Medicine, Asan Medical Center, University of Ulsan College of Medicine, 388-1 Pungnap Dong Songpa Ku, Seoul 138736, Korea
e-mail: yskoh@amc.seoul.kr

A. Gullo (ed.), *Anaesthesia, Pharmacology, Intensive Care and Emergency A.P.I.C.E.*,
DOI: 10.1007/978-88-470-5516-2_1,

seems set to continue in response to the high costs of critical care. This chapter discusses the positive and negative aspects of medical technologies, and the optimal combination of clinical practice and technology that will deliver the best critical care.

1.2 The Technologies Used in Critical Care Medicine

Medical technology is defined as any intervention that may be used for health care. It broadly includes medical equipment, information technology, clinical skills, and healthcare services (Fig. 1.1). Medical technology is developed in tandem with a relevant clinical necessity, with an idea generated at the patient bedside often contributing to this advance. The invention of the stethoscope is a typical example of an ideal coupling of clinical skills and technology. The incessant development of medical technology performs a crucial role in minimizing medical errors and enhancing the quality and effectiveness of care.

Some technologies broaden medical knowledge, improve clinical performance, and lead to the further development of relevant technologies. Radiological imaging and electrical recording on the surface of the human body are regarded as milestone technologies in medicine. Some medical technologies have become essential tools for critically ill patients, such as artificial renal dialysis, mechanical ventilation, and the defibrillator, which are now first-line life saving devices in the ICU. The role of ultrasonography has also been expanding in the ICU. In addition, sometimes a newly introduced technology stimulates new clinical skill development. The pressure support ventilation (PSV) mode is the typical example. The PSV mode was not adopted until critical care physicians recognized its usefulness as a weaning mode, several years after its initial introduction.

An increased understanding of a clinical phenomenon permits physicians to reevaluate daily applications of technologies. For example, an improved understanding of underlying ventilator-associated lung injury led to a modification of

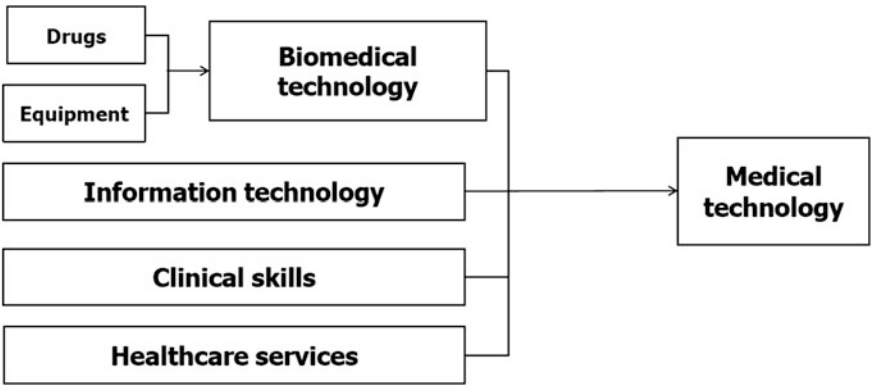

Fig. 1.1 The spectrum of medical technology

ventilation strategies—without equipment change—in cases of acute respiratory distress syndrome (ARDS) [1]. The proven efficacy of low tidal ventilation in the treatment of ARDS led investigators to discourage the use of high-frequency ventilation in adult ARDS patients [2]. Recent advances in extracorporeal membrane oxygenation equipment have enabled a previous poor reputation to be overcome, and this technology now shows efficacy in treating ARDS [3].

1.3 The Influence of Digital Technologies on Critical Care Medicine

The introduction of digital technology has opened up new horizons in clinical practice. Computed tomography, as a representative example of a digitized diagnostic tool, has improved our diagnostic capabilities and extended our understanding of many critical illnesses. The impact of digitized healthcare information technology (IT) on medicine seems to be greater than expected. Through the digitization of clinical data, data storage, and retrieval has become easier, quicker, and more accurate. Electronic medical records (EMRs), picture archiving communication systems, and order communicating systems (OCSs) are examples of

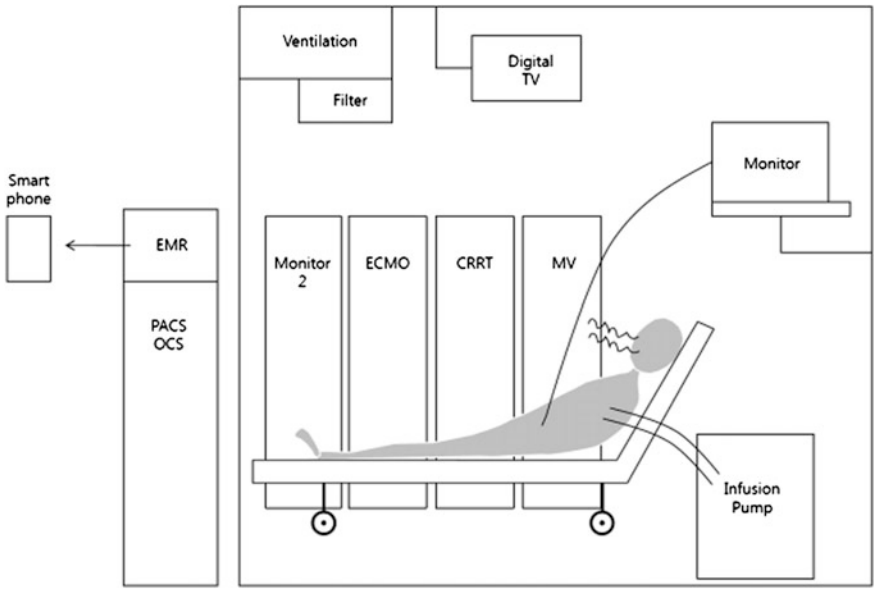

Fig. 1.2 An example of a digitalized ICU environment. Monitoring data from a patient monitor or mechanical ventilator can be automatically transferred to the EMR system.: *CRRT* continuous renal replacement therapy; *ECMO* extracorporeal membrane oxygenation; *EMR* electric medical record; *MV* mechanical ventilation; *OCS* order communicating system; *PACS* picture archiving communication system

recent digital technologies that are increasingly being adopted by hospitals worldwide. EMRs have improved the accessibility, legibility, and storage of patient records. These health ITs have been reported to reduce medication errors and health care costs. A cross-sectional study of urban hospitals in Texas measured the level of automation of each hospital based on physician interactions with the information system, which included medical records, test results, order entries, and decision support. The investigators found in this multihospital study that hospitals with automated notes and records, order entries, and clinical decision support had fewer complications, lower mortality rates, and even lower costs [4].

The ICU is a very good setting to exploit the potential benefits of IT. In fact, IT technology now plays a role in every aspect of the work of a modern ICU, supporting both clinical decisions and care (Fig. 1.2). By connecting to a relevant website through handheld digital equipment or even a smart phone, clinicians can now obtain clinical references that are urgently needed for decision making at the bedside. Through the implementation of management guidelines based on sound medical evidence, the OCS of a hospital can amend essential orders that have been missed and continuously monitor order compliance.

Some monitoring systems, such as a continuous hemodynamic monitor, can give advice on patient management based on specific algorithms. Clinical information can be simultaneously shared between physicians at different hospitals if they are equipped with a common interface for data communication. Telemedicine ICU (Tele-ICU) is an electronic means to link ICUs at different locations, which then assists in medical decision making. Given the shortage of intensive care physicians, Tele-ICU systems could be an alternative mechanism for physicians to manage a larger number of critical care patients and to enable 24 h, 7-day ICU coverage [5]. Robotic support is also now being used as a mobile monitoring device in remote locations. Telemedicine seems to make possible of home-bound ICU care in near future.

As digital technology can generate large data sets, the valuable data could be used by variable stakeholders related to public health care. In the public health sector in the United States, the sharing of large data sets for better critical care policy development has been already initiated. The problem to be encountered is inadequate staffing, training, and resources for data collection [6].

1.4 The Negative Influence of Medical Technologies on Intensive Care Medicine

It has been anticipated in some quarters that advanced technology will provide us with more accurate clinical information and better clinical guidance. The preference of physicians for high technology has also been changing their diagnostic approaches. Even experienced chest physicians depend more on chest-computed tomography than on simple chest X-rays to reduce possible medical errors. Increased medical malpractice disputes are one cause of the increased dependence

of physicians on advanced technology. However, the increased adoption of advanced technology has resulted in an increase in medical expenses. The value of this has generally not been well established in terms of patient outcomes and cost-effectiveness.

Another practical problem relates to the differences in the results obtained when using different equipment that has been developed for the same purpose. These discrepancies may occur due to the different hypotheses and algorithms inherent in the individual equipment. In a study to compare updated hemodynamic monitoring equipment, similar mean CO values were obtained [7]. However, these values often trended differently in response to therapy [7]. The algorithms contained in different devices are based on a particular hypothesis, which may not match the specific condition of the patient in question. Given that clinical decisions have to be made frequently in an ICU setting, trend differences may become a considerable problem for critical care physicians. Nurses can also experience difficulties with the implementation of new and obtrusive technology at the bedside [8].

Organizational issues can also occur when implementing novel technology in the ICU. Physicians may not like to use unfamiliar new technology, and the process of adopting new technology frequently requires a reported benefit, such as in cost or patient handling, and the agreement of other stakeholders. Moreover, high-level technology does not always go hand-in-hand with the interpersonal approaches often required of care providers for more fragile patients and their families. Instead of frequent visits to the critically ill patient's bed, care providers can more easily refer to the clinical information obtained by different devices.

The clinical reasoning ability of a trainee could also be hampered by a high dependence on the management algorithm used in updated monitors. It was reported in an ICU-based cohort study that copying of EMRs among attending and resident physicians was common [9]. Easy copy-and-pasting of the EMR could also lead to deterioration in the clinical reasoning process or in the new data gathering of the related healthcare providers.

Another difficulty encountered by intensivists in the digital technology era is related to family discussions. Patients' families can gather more relevant clinical information through the internet than ever before. However, their incomplete medical information could result in a misunderstanding of the care providers' decisions, resulting in a deterioration of the rapport between care providers and families.

An appropriate audit for an improved patient outcome through IT systems is a highly valuable exercise, as explained above. However, a misused performance measurement by an authorized organization can negatively influence a physician's autonomy in clinical decision making. Currently, medical insurance organizations and health policy makers have begun to measure performance using their own scales, which are based on digitized clinical information and reflect the relationship between the clinical outcome and the medical expense.

1.5 The Optimal Combination of Medical Knowledge and Skills, and Advanced Medical Technologies for Critical Care Medicine

Although effective and proven guidelines can improve patient outcomes [10], clinical guidelines are fully applied to only small groups of patients, as shown by studies into the compliance of low tidal volume strategies with ARDS [11] and surviving sepsis guidelines [12]. In a previous 1-day audit survey into the performances of designated guidelines in French adult ICUs, the clinical guidelines were found to have been fully applied at the bedsides of only 24 % of patients [13]. These results underline the need to both improve the process of implementation and obtain immediate feedback on missed performances. The inherent instant monitoring of IT applications and the ability to immediately respond to physicians' orders has the potential overcome barriers to guideline implementation.

Although the effect of Tele-ICU on patient outcome has not yet been validated, telemedicine appears to be one solution for the 24 h/7-daycoverage required of an ICU. One study has shown that Tele-ICU coverage is associated with a lower ICU mortality and length of stay, but not with lower in-hospital mortality or hospital length of stay [14]. The combination of telemedicine and internet technology may permit the development of home-based monitoring systems for chronically ill patients. Such e-health technology may then enable the proactive management of critically ill patients before their arrival at the hospital. A retrospective analysis has shown that perceived emergencies in nonhospitalized patients occur commonly but require minimal emergent intervention [15]. Early appropriate intervention in such a fragile patient can reduce the length of hospital stay and medical expenses and obtain a better outcome through a simple home-based IT system [16].

Another potential use of IT in the ICU resides in its role as a communication facilitator. If well-designed, e-health technology could positively contribute to intensive care medicine through the enhancement of bilateral communication between healthcare providers and patients' families. It could enable patient-centered ICU development through communication enhancement via various IT tools. It permits the patient's family members that cannot regularly visit the ICU to see the EMR through a social network system (SNS), as long as the healthcare providers and government regulations permit a log into the EMR site for these individuals. The patient's family can also contribute to the management of the patient by providing information that may be missed during history taking. By letting the patient's family follows the decision processes of the ICU care providers through the SNS, these process may be better facilitated. End-of-life care could also be better performed through e-health technologies. Furthermore, the advance directives of patients could be recorded and stored ahead of time at an officially endorsed site.

Through the various levels of medical information on the internet, including hospital homepages, patients can receive undesirable attributions and biased viewpoints against a certain hospital or certain doctors. The impact of this can be

worldwide in the current era of medical tourism, where patients search for cheap, but good quality care. To cope with such a detrimental influence of e-health technology, healthcare stakeholders should strengthen their sensitivity to relevant medical ethical considerations. Intensive care physicians should carefully consider what they can do and what they should do. These physicians should make balanced decisions about cost-performance and ethical approaches to the implementation of newly developed medical technologies when treating a critically ill patient. In resource-limited ICUs, more evidence-based approaches should be performed to select essential and affordable technologies.

We know that better clinical outcomes can be achieved through both relevant medical knowledge and the appropriate technological support. The importance of careful clinical observation and an experienced integrated clinical decision could not be underestimated even in the high-technology ICU care environment infuture. The truth of medicine is that many diagnoses can be made based on history alone or based on history and physical examination. Expensive tests often confirm what is found during the history and physical examination. Therefore, the importance of adequate staffing of critical care providers together with a well-prepared critical care training system should not be underestimated by hospital administrators and health policy makers.

It is becoming increasingly common for government bodies, healthcare providers, funders, and consumers to seek measures of the quality of critical care. It must be ensured that the quality of the ICU data is sufficiently high to enable stakeholders to confidently use quality of care measures. For better data gathering, associated resource enhancement, including updated technology and improved staffing and training, is needed. Furthermore, the development of an internationally applicable common interface for ICU patient data exchange is urgently required.

1.6 Conclusion

Technology and medical practices will always change and adapt over time. The most desirable advances in medical technology would be to simplify complex procedures and make them less error prone. Medical technology also has to be further focused on reducing the cost of public health and improving ICU care quality. To achieve these goals, physicians should enter into effective partnerships with the technology developers, who are often not familiar with the requirements of an ICU. In addition, all of these processes should be performed in ethical ways to avoid undesirable conflicts of interest.

Critical care providers will be challenged to keep pace with rapidly advancing technologies and their diverse roles in ICU care. To cope with these requirements, critical care providers, hospital administrators, and healthcare policy makers should look beyond traditional medical practice, seeking lessons on quality

assurance from industry (e.g., aviation). Modern ICU quality improvement initiatives that aim to ensure evidence-based best practice could be achieved through the balanced coupling of clinical practice and technology in critical care. In medical resource-poor countries, the adoption of a new technology in individual ICUs should be based on its known efficacy, user consensus, and the guidance of the team leader for better ICU care. Its usefulness should be confirmed by its cost and benefit aspects compared with comparable tools.

References

1. The Acute Respiratory Distress Syndrome Network (2000) Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med 342:1301–1308
2. Ferguson ND, Cook DJ, Guyatt GH et al (2013) High-frequency oscillation in early acute respiratory distress syndrome. N Engl J Med 368:795–805
3. Peek GJ, Mugford M, Tiruvoipati R et al (2009) Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. Lancet 374:1351–1363
4. Amarasingham R, Plantinga L, Diener-West M, Gaskin DJ, Powe NR (2009) Clinical information technologies and inpatient outcomes: a multiple hospital study. Arch Intern Med 169:108–114
5. Young LB, Chan PS, Cram P (2011) Staff acceptance of tele-ICU coverage: a systematic review. Chest 139:279–288
6. Hewson-Conroy KM, Tierney LT, Burrell AR (2012) Assessment and perceptions of intensive care data quality, reporting and use: a survey of ICU directors. Anaesth Intensive Care 40:675–682
7. Hadian M, Kim HK, Severyn DA, Pinsky MR (2010) Cross-comparison of cardiac output trending accuracy of LiDCO, PiCCO, FloTrac and pulmonary artery catheters. Crit Care 14:R212
8. McGrath M (2008) The challenges of caring in a technological environment: critical care nurses' experiences. J Clin Nurs 17:1096–1104
9. Thornton JD, Schold JD, Venkateshaiah L, Lander B (2013) Prevalence of copied information by attendings and residents in critical care progress notes. Crit Care Med 41:382–388
10. Ferrer R, Artigas A, Levy MM et al (2008) Improvement in process of care and outcome after a multicenter severe sepsis educational program in Spain. JAMA 299:2294–2303
11. Young MP, Manning HL, Wilson DL et al (2004) Ventilation of patients with acute lung injury and acute respiratory distress syndrome: has new evidence changed clinical practice? Crit Care Med 32:1260–1265
12. Phua J, Koh Y, Du B et al (2011) Management of severe sepsis in patients admitted to Asian intensive care units: prospective cohort study. BMJ 342:d3245
13. Leone M, Ragonnet B, Alonso S et al (2012) Variable compliance with clinical practice guidelines identified in a 1-day audit at 66 French adult intensive care units. Crit Care Med 40:3189–3195

14. Young LB, Chan PS, Lu X, Nallamothu BK et al (2011) Impact of telemedicine intensive care unit coverage on patient outcomes: a systematic review and meta-analysis. Arch Intern Med 171:498–506
15. Dechert TA, Sarani B, McMaster M et al (2013) Medical emergency team response for the non-hospitalized patient. Resuscitation 84:276–279
16. Offner PJ, Heit J, Roberts R (2007) Implementation of a rapid response team decreases cardiac arrest outside of the intensive care unit. J Trauma 62:1223–1227; discussion 1227–1228