Structured Approach to Early Recognition and Treatment of Acute Critical Illness

O. Kilickaya, B. Bonneton, and O. Gajic

Introduction: Global Burden of Critical Illness

Well-known global health priorities (malaria, pneumonia, sepsis, diarrhea, human immunodeficiency virus [HIV], tuberculosis, trauma), although very different threats to an individual's health, share a common consequence: Development of acute, life-threatening illness. In the developed world, such illness is routinely treated in an intensive care unit (ICU) by highly specialized physicians, nurses and support staff. This model of intensive care is spreading rapidly to low and middle income countries and as it spreads, challenges and limitations to this model arise [1].

With an estimated $1000–20,000 per quality-adjusted life year (QALY) gained, critical care support for potentially reversible acute medical or surgical illness should be one of the most cost-effective health care interventions [2, 3]. Unfortunately, incomplete knowledge of the best practices by front-line clinicians and delayed, error-prone care delivery processes are ubiquitous threats to patient safety and commonly offset the potential benefits of critical care support. This is particularly important early in the course of critical illness, when errors and

O. Kilickaya
Department of Internal Medicine, Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, Minnesota USA
Department of Anesthesiology and Reanimation, Gulhane Military Medical Faculty, Ankara, Turkey

B. Bonneton
Department of Internal Medicine, Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, Minnesota USA
Department of Emergency Medicine, Rene Arbeltier Hospital, Coulommiers, France

O. Gajic ✉
Department of Internal Medicine, Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, Minnesota USA
e-mail: gajic.ognjen@mayo.edu

J.-L. Vincent (Ed.), *Annual Update in Intensive Care and Emergency Medicine 2014*,
DOI 10.1007/978-3-319-03746-2_51,

delays in appropriate care often lead to costly complications and poor outcomes, even in advanced hospital settings. In resource-poor settings, inadequate human resources and training present additional barriers to safe and effective use of life-saving procedures. Simple interventions, such as early recognition and treatment of cardio-respiratory failure, low tidal volume mechanical ventilation, early appropriate antimicrobial treatment, physical therapy, deep vein thrombosis and stress ulcer prophylaxis, require little specialized equipment but are crucial to successful outcome of critically ill patients [4]. Accordingly, these interventions have to be systematically implemented without omission or delay. This seemingly simple and straightforward task has proven to be an enormous challenge and nothing but a distant dream in hospitals worldwide.

Why are Errors and Complications so Prevalent in Acute Care Settings?

Although medical technologies and knowledge are continuously improving, there is overwhelming evidence of persistent error [5] and poor real-world compliance with evidence-based practices in acute care hospitals [6–8]. Critically ill patients are particularly prone to medical errors because of inherent complexity involving multiple organ systems and the immediacy of the decision-making required. Errors of omission are as common as those of commission with cumulative failures in a multi-step process encumbering exponentially on a patient's outcome, inevitably leading to development of costly complications (Table 1).

Within the interdisciplinary nature of intensive care, clinicians permanently face multitasking and interruptions. Data overload, meaningless complexity, interruptions, administrative burden, ineffective regulatory requirements, and fragmented provider-based (rather than patient-based) care are some of the most important barriers to error prevention in hospital environments. Care delivery is further impaired by poor communication, inadequate structure, staffing issues and wrong incentives. These errors persist not because physicians and nurses are ignorant, but because the current systems of care make it very difficult to implement the right decisions [9].

Table 1 The chance for omission or error increases exponentially with the number of steps in a complex multi-step process emphasizing the need for very high reliability in each step. Adapted from [49] with permission

Probability of Success for Each Step in the Process				
Number of Steps	0.95	0.990	0.999	0.999999
1	0.95	0.990	0.999	0.9999
25	0.28	0.78	0.98	0.998
50	0.08	0.61	0.95	0.995
100	0.006	0.37	0.90	0.990

The "Checklist Manifesto": Role of Checklists in Enhancing Patient Safety and Prevention of Medical Error [10]

Studies of human error have identified the key role of cognitive ergonomics and human factors engineering in designing improved care delivery processes and devices [8, 9]. Embracing a safety culture, limiting the number of steps ('less is more'), enhancing and prompting clear prioritized information, patient- and family-centered care delivery (integration of values, beliefs and advanced directives), improved communication and coordination (hand-offs, physician extenders) are all needed for safe and efficient critical care delivery. Considering the exponential spreading of medical knowledge, it appears obvious that clinician memory cannot store and retrieve all of it, particularly during acute care support [9]. Medical textbooks and current guidelines provided by major scientific societies display exhaustive information for best practice, but may be complex to use as an efficient decision support at the point-of-care [11].

Multiple tools have recently been developed, tested and validated to enhance both efficiency and fidelity of acute care delivery. These include: Multidisciplinary rounds, daily goals of care sheets, smart alarms, dashboards and decision supports. Analogous to the complex industry environment (e. g., aviation, nuclear power plants), simplified checklists and care 'bundles' have been recently introduced on a large scale in various medical settings (Table 2) [12, 13].

Worldwide implementation of a relatively simple World Health Organization (WHO) surgical safety checklist led to improved outcomes across three continents [14]. Protocolized procedure bundles have similarly lead to the dramatic reduction in vascular device complications across multiple institutions [12]. The introduction of "goals of care sheet" [15] and checklist prompting during daily rounds [16] have both led to substantial improvements in efficiency and reliability of daily plan of care, and were associated with decreased complications.

In order to be helpful at the point-of-care, checklists and algorithms need to focus on brief prioritized information [17, 18]. Checklist effectiveness also relies on an appropriate display [19] and depends on the integration of the tool into bedside practice. This is often achieved using verbal prompting by the team leader or another designated clinician [20, 21]. Standardized processes spur teams to interact and communicate to find the best strategy in ensuring compliance with each care component [22].

'Golden Hours': The Importance of Error-free Care Early in the Course of Acute Critical Illness

The burden of medical error, omission and waste are especially exacerbated during the early course of critical illness when timely and efficient intervention are of paramount importance for patient outcome. The consequences of inadequate care delivery at the onset of acute critical illness are elegantly summarized in the words

Table 2 Representative examples of the use of checklists in various acute care environments

Settings	Checklist	Author, year [5]	Aim
Operating room	Anesthesia crisis management manual	Runciman, 2005 [36]	24 specific anesthesia crisis management sub-algorithms
	Sepsis during anesthesia management checklist	Myburgh, 2005 [50]	Provide a structured approach for the management of sepsis occurring in association with anesthesia
	Cesarean delivery anesthesia	Hart, 2005 [51]	Improving anesthesia preparation for caesarean delivery
	The WHO surgical safety checklist	Haynes, 2009 [52]	Address key safety steps during perioperative care to reduce rates of death and complications
	SURPASS checklist	De Vries, 2009 [53]	SURgical Patient Safety System: Address surgical errors and adverse events during daily clinical practice, from admission to discharge
	Obstetric safe surgery checklist	Rao, 2010 [54]	WHO surgical safety checklist adapted to obstetric specificities
	Operating room crisis checklists	Ziewacz, 2011 [55]	Improving care during 12 of the most common operating room crises
	Surgical safety	Bliss, 2012 [56]	Implementation of comprehensive surgical checklist
Intensive care unit	Diagnosis of brain death	Young, 1991 [57]	Proper assessment and documentation to the declaration of brain death
	Intensive care delirium screening checklist	Bergeron, 2001 [58]	Quickly identify delirious patient, with earlier diagnosis, earlier intervention and better care
	Improving communication in the ICU	Pronovost, 2003 [15]	Daily goals implementation improve understanding of goals of care and overall patient outcomes
	Room opening checklist	Quinio, 2003 [59]	Improve adequacy of room's equipment endowment
	Weaning from mechanical ventilation in intensive care patients	Walsh, 2004 [60]	Checklist of metabolic, cardiorespiratory and neurological criteria that suggested that patients should start the weaning process (successful weaning from ventilator prediction)
	Catheter-related bloodstream infection (CR-BSI) multifaceted interventions	Berenholtz, 2004 [61]	Eliminate CR-BSIs with staff education, procedure cart, catheter removal daily prompting, evidence-based guidelines checklist
	Improving care for the ventilated patient	Berenholtz, 2004 [62]	Daily rounding checklist to improve mechanically ventilated patient outcome
	Withdrawal of life support (WOLS) standardized process	Hall, 2004 [63]	Improve conduct of end-of-life care
	Catheter-related bloodstream infections	Pronovost, 2006 [12]	Evidence-based intervention to reduce the incidence of infection

Table 2 *Continuation*

Settings	Checklist	Author, year [5]	Aim
Intensive care unit	Daily quality rounding checklist	DuBose, 2008 [21]	Increase compliance to prophylactic measures relative to main ICU complications
	Improving compliance to protocols and objectives in ICU	Byrnes, 2009 [20]	Mandatory verbal review of checklist to improve consideration and implementation of ICU best practices
	Checklist for lung injury prevention (CLIP)	Lee, 2012 [64]	Improving early recognition and utilization of good practices for patients at high-risk for ALI/ARDS
Emergency department	Trauma patient pre-transfer checklist	Harahill, 1990 [65]	Checklist to promptly prepare patient for transfer
	Sepsis treatment checklist	Djogovic, 2012 [66]	Optimize sepsis care in emergency departments
Other acute care settings	Checklists and reminders	Wolff, 2004 [67]	Checklists and reminders in clinical care pathways for inpatients admitted for acute myocardial infarction or stroke (key best practices)
	WHO patient care checklist: new influenza A (H1N1)	WHO, 2009 [68]	Highlights areas of care for the management of new influenza A (H1N1)

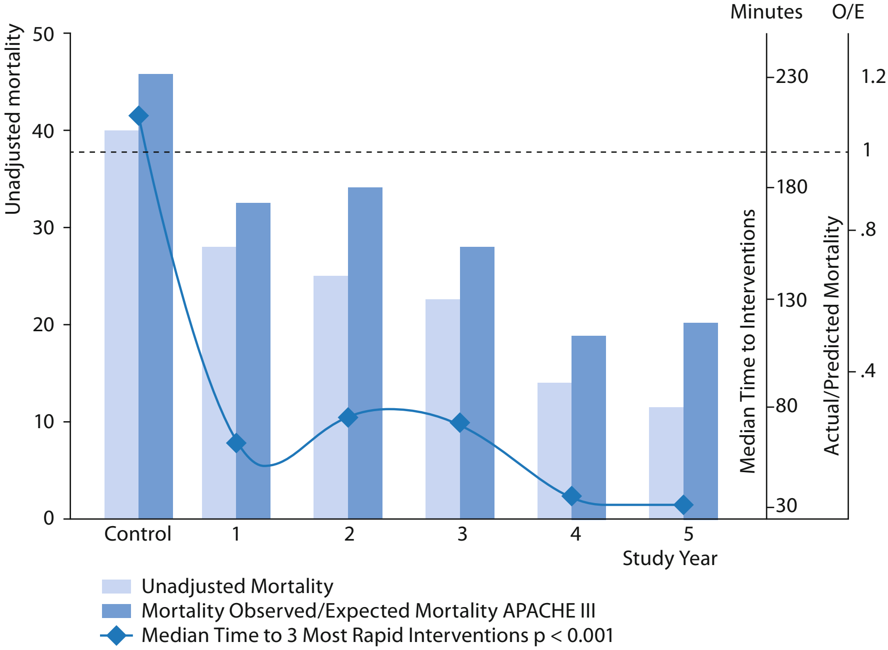

Fig. 1 Golden hours: Importance of minor delays in applying rapid interventions to acutely ill patients in shock. From [28] with permission

of one of the fathers of critical care support, the late Peter Safar: "The most sophisticated intensive care becomes unnecessarily expensive terminal care ..." [23].

This intuitive concept, renowned as the 'Golden Hour', has informed trauma care since the second half of the 20th century [24, 25], but has yet to be widely adopted in most other critical care conditions. The non-linear trajectory and time-sensitive nature of acute critical illness is characteristic of the complex systems [26]. During the vulnerable period immediately prior to 'phase transition', seemingly minor errors, omissions or delays can profoundly alter the patient trajectory. Simple interventions (fluid bolus, oxygen, transfusion, thrombolytic reperfusion), while beneficial during early hours of critical illness may lose effectiveness or even become harmful later in the course of critical illness (after the 'phase transition') [27]. The importance of timely recognition and appropriate treatment of acute critical illness is nicely illustrated in Fig. 1, showing the importance of minute delays in the rapid application of basic critical care support to patients in shock [28]. More recently, a multicenter quality improvement intervention targeting patients with severe sepsis in the emergency department showed that rapid implementation of early bundle elements (i. e., appropriate empiric antimicrobials, fluid bolus, lactate) was associated with aborted progression of organ failures making the patients "ineligible" for subsequent bundle elements (inotropes, steroids, transfusions, low tidal volume ventilation for ARDS) [29].

Regardless of how advanced hospital settings are, expected advantages of critical care support will be impaired if front-line clinicians fail to apply best practices in a timely manner. Therefore, avoiding diagnostic errors and therapeutic delays during these first minutes and hours of the care process ('golden hours') is necessary to prevent costly complications, preventable death and disability [16, 30].

Despite the notion of the importance of 'golden hours, Table 2 shows that the most acute care checklists are concerned with day-to-day care and procedure management. The critical, early period that often occurs outside of the ICU (in the emergency department, hospital ward or recovery room) is largely ignored and checklist use anecdotal. This gap is particularly deep in non-surgical settings where checklists and algorithms generally do not address early recognition and treatment of acute illness, apart from cardiopulmonary resuscitation (CPR) [31], which is often too late!

Structured Approach to Early Recognition and Treatment of Acute Critical Illness

The traditional linear approach, from history and examination to diagnosis and treatment, too often leads to delays in appropriate care and an alternative, iterative approach of addressing life-threatening physiologic disturbances and reviewing the response concurrently with the identification and treatment of underlying condition has been recommended (Fig. 2) [32, 33].

Accurate diagnosis is often elusive during the early stages of critical illness in which vastly different underlying conditions may trigger similar and/or interrelated physiologic disturbances leading to a limited number of acute presentations

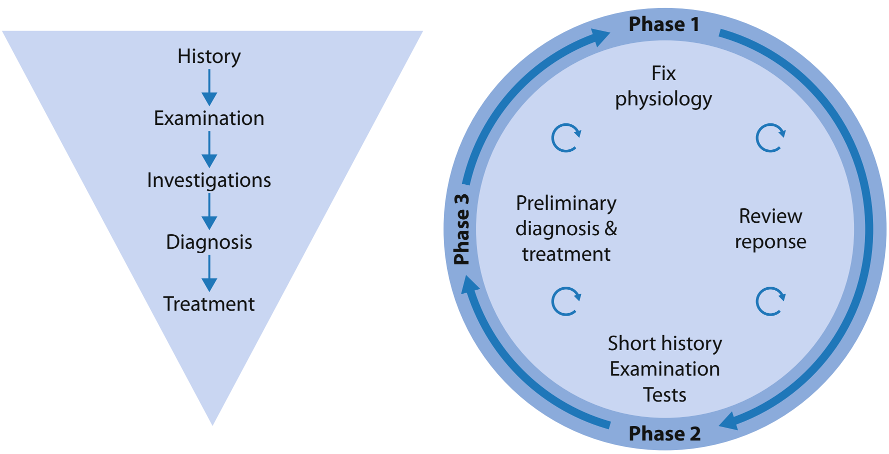

Fig. 2 Contrasting linear vs. iterative approach to initial management of acutely ill patients, adapted from the ESICM PACT module on Clinical Examination [32]

(Box 1) [34]. The timely and appropriate management of these key presentations followed by syndromic diagnoses (shock, respiratory failure, increased intracranial pressure, acute coronary syndrome, etc.), often without full understanding of the underlying condition, constitutes the basics of the acute care of critically ill patients. Keeping in mind the challenges clinicians are facing during early stages of acute critical illness, and the fact that experienced specialist help is often delayed, it is not difficult to imagine the advantages of a systematic and disciplined method that can consistently combine and articulate key diagnostic and therapeutic interventions [35]. Of note, even experienced clinicians are prone to making basic errors during emergency situations exposing patients to harm and clinicians to litigation [36].

Box 1:
Common Presentations of Life-threatening Conditions

- Shortness of breath
- Hypotension
- Chest pain
- Arrhythmia
- Altered mental state
- Abdominal pain
- Sepsis
- Gastrointestinal bleeding
- Trauma
- Intoxication/overdose
- Postoperative

One of the first examples to the systematic and standardized approach to life-threatening illness is the development of the mnemonic 'ABC' by the late Dr. Safar and colleagues in the early 1960 s in order to standardize the immediate care of patients with cardiac arrest [37]. In the 1970 s, Dr. Styner extended the context of the initial ABC approach for the evaluation of critically injured trauma patients and formed the basis of the Advanced Trauma Life Support courses [38]. The ABCDE approach has been implemented into trauma settings successfully for many years. Box 2 provides an example of the ABCDE checklist suitable for various acute care environments.

Box 2:
Example of an ABCDE checklist

A	Airway compromise Stridor Wheezing
B	Poor air entry Crackles Work of breathing
C	[1] EKG monitor Weak pulse Mottling
D	[2] AVPU Seizure Focal deficit
E	Abdominal distension Bleeding [3] Skin

[1] Sinus, bradycardia, supraventricular tachycardia, ventricular tachycardia, ventricular fibrillation, ST changes
[2] Alert, verbal responsive, pain responsive, unresponsive
[3] Edema, rash, jaundice, wound

The advantage of the structured approach to life-threatening emergencies has been elegantly demonstrated in a recent study [18]. In this study, the use of checklists by operating room teams markedly decreased critical omissions (23 % vs. 6 %, $p < 0.001$) in a high fidelity simulation of 106 surgical crises scenarios. Unfortunately, apart from CPR, which is too late, a similar checklist approach is largely missing during golden hours outside operating room and trauma settings [36].

Figure 3 outlines the key elements of a structured approach to acute life-threatening illness or injury: Primary survey to address immediate life-threats (need for CPR, ABCDE bundle) followed by secondary survey to assess each organ system, identify relevant syndromes and, in parallel, initiate emergent therapies.

Emerging Technologies: Information Displays, Cloud Computing and Mobile Devices

The advances in information technology, medical informatics and human factors engineering, have provided a tremendous opportunity for the development of novel and user-friendly checklists and decision support tools that can be widely applied in a complex and busy acute care settings [9]. To be successful, these applications need to reduce information overload and the potential for error, facilitate adherence to practice guidelines and enable clear communication and collaborative decision

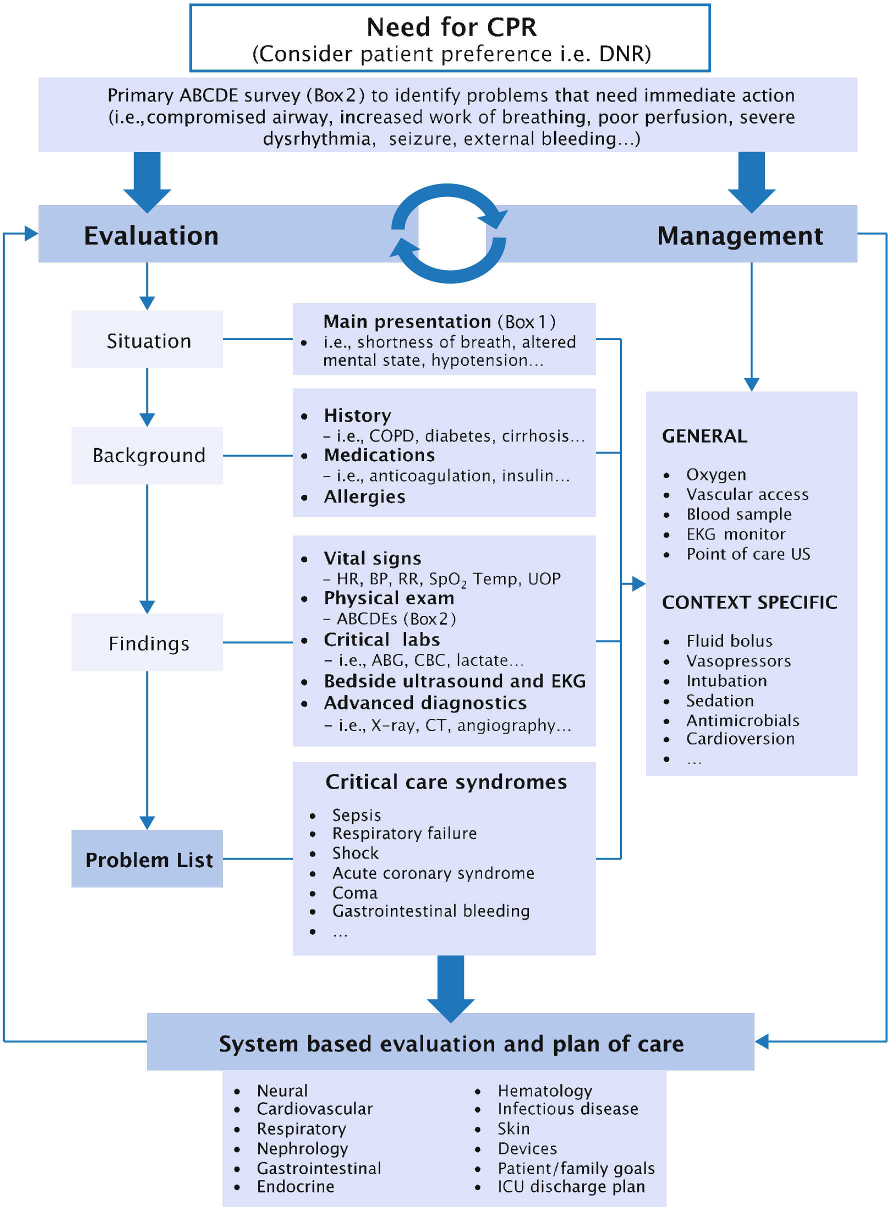

Fig. 3 Outline of the structured approach to early recognition and treatment of acute illness. ABG: arterial blood gases; CBC: complete blood count; COPD: chronic obstructive pulmonary disease; CPR: cardiopulmonary resuscitation; CT: computed tomography; DNR: do-not-resuscitate; ECG: electrocardiography; HR: heart rate; ICU: intensive care unit; RR: respiratory rate; SpO_2: peripheral oxygen saturation; Temp: body temperature; UOP: urine output; US: ultrasound

making between all members of health care team, patients and families. To facilitate high quality, high value health care behaviors, information display and functionality need to be designed using cognitive ergonomic principles and integrated into the clinician workflow in a manner that facilitates, rather than disrupts, care delivery.

Two years of provider surveys and field observation in medical and surgical ICUs of the Mayo Clinic have provided a robust framework for the prioritization of high value data for the management of critically ill patients [39]. The investigators identified no more than 50 data points that are commonly used by ICU experts. These 50 data points are prioritized on the novel user interface depending on the task at hand [40]. Knowledge translation is facilitated by smart alerts and real time access to evidence-based checklists. Collaborative workspace provides a shared view of the plan of care with patient specific tasks, status checks and reminders enabling the clear communication of the goals of care and their status to all members of the multidisciplinary team including the patient and family. Availability of key patient, process and outcome data in an electronic format provides easy access to scheduled and on demand reports of quality metrics and outcomes.

Using real-time data feeds and standardized patient care tasks in a simulated acute care environment, this novel interface was shown to have a significant advantage over the conventional electronic medical record in reducing provider cognitive load and errors [41]. Direct comparisons between electronic and paper checklists have not been done. Despite the potential pitfalls (need for additional training, reliable hardware, software and network) electronic checklists and decision supports offer some compelling advantages including, but not limited to, global access using mobile computing devices, standardized updates based on new knowledge and wide user feedback, versatile display capabilities (hyperlinks, videos and animations) which facilitate the processing of vast patient information and medical knowledge. In addition electronic tools obviate the need for paper products and its transport, thereby reducing associated cost and pollution.

Rapidly increasing access to mobile phones and cellular networks even in remote and resource-poor settings have recently enabled previously unimaginable, successful quality improvement interventions in rural Africa [42]. Cloud computing technology is also evolving swiftly, providing easy shared access to information with an almost unlimited/scalable storage capability increasing the ability for widespread knowledge translation. Using the approach outlined above and inspired by a surgical crisis checklist [17, 18], a multidisciplinary, international team of acute care clinicians is testing the effectiveness of electronic decision support (CERTAIN – Checklist for Early Recognition and Treatment of Acute Illness) in critical care environments across Eastern Europe, Asia, Africa and Central America [43, 44].

Implementing Checklists at the Bedside of Acutely Ill Patients

Regardless of the format (paper vs. electronic), checklist implementation often encounters cultural barriers, particularly among physicians. Perceptions on limitation of autonomous judgment, checklist dependency and questioning someone's seniority, knowledge and skill pose significant challenges to the implementation process [45]. Clinicians are often worried about over-standardized care processes ignoring the critical illness complexity ('cookbook medicine'). But despite these challenges, the checklist approach provides a framework to ensure the best care and a guardrail to avoid errors and omissions during diagnostic and therapeutic courses. Rather than replacing the bedside clinician, these tools are designed to help structure his/her reasoning (focus, precision, reminder, lucidity) and action in spite of facing fatigue and stressful conditions [46].

Assessing the information needs at the point of care is a key prerequisite for designing improved care delivery processes and devices that can fit in clinician workflow. PDSA (Plan-Do-Study-Act) cycles of field observation, surveys, interviews, workflow observations are necessary in order to meet the needs of frontline clinicians. Beta testing and validation of such tools in a simulated environment is essential before implementing them into clinical practice. Similar to any quality improvement projects, the checklist should be reviewed, refined and updated regularly. Senior leadership support is essential to overcome political barriers to the patient-centered (as opposed to the provider-centered) checklist processes. "The model for improvement" [47] is a powerful framework used by many health care organizations to accelerate the improvement of health care processes and outcomes [13, 48].

Conclusions

To fully realize the anticipated patient benefit while treating acute critical illness, clinicians ought to embrace systematic reasoning and a reliable approach to promote early recognition and ensure timely and appropriate treatment. In the current system, much of the effort in critical care is reactionary rather than proactive in implementing best practices aimed at preventing complications. A structured, reliable and error-free approach to the management of acutely ill or injured patients during the early, most vulnerable period is facilitated by point-of-care checklists and algorithms containing brief prioritized information. This approach is rapidly spreading in trauma and operating room settings and other acute care environments should follow soon.

References

1. Adhikari NK, Fowler RA, Bhagwanjee S, Rubenfeld GD (2010) Critical care and the global burden of critical illness in adults. Lancet 376:1339–1346
2. Barie PS, Ho VP (2012) The value of critical care. Surg Clin North Am 92:1445–1462
3. Linko R, Suojaranta-Ylinen R, Karlsson S, Ruokonen E, Varpula T, Pettila V (2010) One-year mortality, quality of life and predicted life-time cost-utility in critically ill patients with acute respiratory failure. Crit Care 14:R60
4. Kumar A, Roberts D, Wood KE et al (2006) Duration of hypotension before initiation of effective antimicrobial therapy is the critical determinant of survival in human septic shock. Crit Care Med 34:1589–1596

5. Kohn LT, Corrigan JM, Donaldson MS (2000) To Err is Human : Building a Safer Health System. National Academy Press, Washington
6. Pronovost PJ, Berenholtz SM, Ngo K et al (2003) Developing and pilot testing quality indicators in the intensive care unit. J Crit Care 18:145–155
7. Ilan R, Fowler RA, Geerts R, Pinto R, Sibbald WJ, Martin CM (2007) Knowledge translation in critical care: factors associated with prescription of commonly recommended best practices for critically ill patients. Crit Care Med 35:1696–1702
8. Moreno RP, Rhodes A, Donchin Y (2009) Patient safety in intensive care medicine: the Declaration of Vienna. Intensive Care Med 35:1667–1672
9. Pickering BW, Litell JM, Herasevich V, Gajic O (2012) Clinical review: the hospital of the future – building intelligent environments to facilitate safe and effective acute care delivery. Crit Care 16:220
10. Gawande A (2010) The Checklist Manifesto : How To Get Things Right, 1st edn. Metropolitan Books, New York
11. Wyer PC, Rowe BH (2007) Evidence-based reviews and databases: are they worth the effort? Developing evidence summaries for emergency medicine. Acad Emerg Med 14:960–964
12. Pronovost P, Needham D, Berenholtz S et al (2006) An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med 355:2725–2732
13. Gawande AA, Arriaga AF (2013) A simulation-based trial of surgical-crisis checklists. N Engl J Med 368:1460
14. Treadwell JR, Lucas S, Tsou AY (2014) Surgical checklists: a systematic review of impacts and implementation. BMJ Qual Saf (in press)
15. Pronovost P, Berenholtz S, Dorman T, Lipsett PA, Simmonds T, Haraden C (2003) Improving communication in the ICU using daily goals. J Crit Care 18:71–75
16. Weiss CH, Moazed F, McEvoy CA et al (2011) Prompting physicians to address a daily checklist and process of care and clinical outcomes: a single-site study. Am J Respir Crit Care Med 184:680–686
17. Gawande A (2007) The checklist: if something so simple can transform intensive care, what else can it do? New Yorker 10:86–101
18. Arriaga AF, Bader AM, Wong JM et al (2013) Simulation-based trial of surgical-crisis checklists. N Engl J Med 368:246–253
19. Lee MJ, Gershengorn HB, Dinkels M et al (2012) Checklist For Lung Injury Prevention (CLIP): A pilot study on implementation across multiple hospitals and multiple clinical areas. American Thoracic Society, San Francisco, A6567 (abst)
20. Byrnes MC, Schuerer DJ, Schallom ME et al (2009) Implementation of a mandatory checklist of protocols and objectives improves compliance with a wide range of evidence-based intensive care unit practices. Crit Care Med 37:2775–2781
21. DuBose JJ, Inaba K, Shiflett A et al (2008) Measurable outcomes of quality improvement in the trauma intensive care unit: the impact of a daily quality rounding checklist. J Trauma 64:22–29
22. Resar R, Pronovost P, Haraden C, Simmonds T, Rainey T, Nolan T (2005) Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. Jt Comm J Qual Patient Saf 31:243–248
23. Safar P (1974) Critical care medicine – quo vadis? Crit Care Med 2:1–5
24. Cowley RA (1975) A total emergency medical system for the State of Maryland. Md State Med J 24:37–45
25. Cowley RA (1977) Trauma center. A new concept for the delivery of critical care. J Med Soc N J 74:979–987
26. Dong Y, Chbat NW, Gupta A, Hadzikadic M, Gajic O (2012) Systems modeling and simulation applications for critical care medicine. Ann Intensive Care 2:18
27. Rivers E, Nguyen B, Havstad S et al (2001) Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 345:1368–1377

28. Sebat F, Musthafa AA, Johnson D et al (2007) Effect of a rapid response system for patients in shock on time to treatment and mortality during 5 years. Crit Care Med 35:2568–2575
29. Miller RR 3rd, Dong LNNC et al (2013) Multicenter implementation of a severe sepsis and septic shock treatment bundle. Am J Respir Crit Care Med 188:77–82
30. Pronovost PJ, Berenholtz SM, Needham DM (2008) Translating evidence into practice: a model for large scale knowledge translation. BMJ 337:a1714
31. Nolan JP, Soar J, Zideman DA et al (2010) European Resuscitation Council Guidelines for Resuscitation 2010 Section 1. Executive summary. Resuscitation 81:1219–1276
32. McAuley D, Hillman KM, Bion J (2005) Clinical examination. Ramsay G, Hinds C (eds) European Society of Intensive Care Medicine (ESICM) Patient-centered Acute Care Training (PACT) Module
33. Kortbeek JB, Turki ASA, Ali J et al (2008) Advanced trauma life support, 8th edition, the evidence for change. J Trauma 64:1638–1650
34. Mackenzie R, Sutcliffe RC (2002) Immediate assessment and management of acute medical emergencies. J R Army Med Corps 148:276–287
35. Balas MC, Vasilevskis EE, Burke WJ et al (2012) Critical care nurses' role in implementing the "ABCDE bundle" into practice. Crit Care Nurse 32:35–38
36. Runciman WB, Kluger MT, Morris RW, Paix AD, Watterson LM, Webb RK (2005) Crisis management during anaesthesia: the development of an anaesthetic crisis management manual. Qual Saf Health Care 14:e1
37. Safar P, Brown TC, Holtey WJ, Wilder RJ (1961) Ventilation and circulation with closed-chest cardiac massage in man. JAMA 176:574–576
38. Styner JK (2006) The birth of advanced trauma life support. J Trauma Nurs 13:41–44
39. Pickering BW, Gajic O, Ahmed A, Herasevich V, Keegan MT (2013) Data utilization for medical decision making at the time of patient admission to ICU. Crit Care Med 41:1502–1510
40. Pickering BW, Herasevich V, Ahmed A, Gajic O (2010) Novel representation of clinical information in the ICU: Developing user interfaces which reduce information overload. Appl Clin Inform 1:116–131
41. Ahmed A, Chandra S, Herasevich V, Gajic O, Pickering BW (2011) The effect of two different electronic health record user interfaces on intensive care provider task load, errors of cognition, and performance. Crit Care Med 39:1626–1634
42. Zurovac D, Sudoi RK, Akhwale WS et al (2011) The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial. Lancet 378:795–803
43. Checklist for early recognition and treatment of acute illness (CERTAIN) official website (2013) Available at http://www.icertain.org. Accessed November 2013
44. The iCertain Project (2013) European Society of Critical Care Medicine (ESICM), Minutes of the Global Intensive Care working group meeting, Brussels. Available at http://www.esicm.org/upload/5191ebaf1b026-protokollmeetingbrusselsmarch2013.pdf. Accessed November 2013
45. Hales BM, Pronovost PJ (2006) The checklist – a tool for error management and performance improvement. J Crit Care 21:231–235
46. Sexton JB, Thomas EJ, Helmreich RL (2000) Error, stress, and teamwork in medicine and aviation: cross sectional surveys. BMJ 320:745–749
47. Langley GL, Nolan KM, Nolan TW, Norman CL, Provost LP (2009) The improvement guide : a practical approach to enhancing organizational performance, 2nd edn. Jossey-Bass Publishers, San Francisco, California
48. Winters BD, Gurses AP, Lehmann H, Sexton JB, Rampersad CJ, Pronovost PJ (2009) Clinical review: checklists – translating evidence into practice. Crit Care 13:210
49. Botwinick L, Bisognano M, Haraden C (2006) Leadership Guide to Patient Safety. Institute for Healthcare Improvement (IHI) Innovation Series white paper. IHI, Cambridge, Massachusetts

50. Myburgh JA, Chapman MJ, Szekely SM, Osborne GA (2005) Crisis management during anaesthesia: sepsis. Qual Saf Health Car 14:e22
51. Hart EM, Owen H (2005) Errors and omissions in anesthesia: a pilot study using a pilot's checklist. Anesth Analg 246–250
52. Haynes AB, Weiser TG, Berry WR et al (2009) A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med 360:491–499
53. de Vries EN, Hollmann MW, Smorenburg SM, Gouma DJ, Boermeester MA (2009) Development and validation of the SURgical PAtient Safety System (SURPASS) checklist. Qual Saf Health Care 18:121–126
54. Rao K, Lucas DN, Robinson PN (2010) Surgical safety checklists in obstetrics. Int J Obstet Anesth 19:235–236
55. Ziewacz JE, Arriaga AF, Bader AM et al (2011) Crisis checklists for the operating room: development and pilot testing. J Am Coll Surg 213:212–217
56. Bliss LA, Ross-Richardson CB, Sanzari LJ et al (2012) Thirty-day outcomes support implementation of a surgical safety checklist. J Am Coll Surg 215:766–776
57. Young GB, Frewen T, Barr HW et al (1991) Checklist for diagnosis of brain death. Can J Neurol Sci 18:104
58. Bergeron N, Dubois MJ, Dumont M, Dial S, Skrobik Y (2001) Intensive Care Delirium Screening Checklist: evaluation of a new screening tool. Intensive Care Med 27:859–864
59. Quinio P, Baczynski S, Dy L, Ferrec G, Catineau J, de Tinténiac A (2003) Evaluation of a medical equipment checklist before intensive care room opening. Ann Fr Anesth Reanim 22:284–290
60. Walsh TS, Dodds S, McArdle F (2004) Evaluation of simple criteria to predict successful weaning from mechanical ventilation in intensive care patients. Br J Anaesth 92:793–799
61. Berenholtz SM, Pronovost PJ, Lipsett PA et al (2004) Eliminating catheter-related bloodstream infections in the intensive care unit. Crit Care Med 32:2014–2020
62. Berenholtz SM, Milanovich S, Faircloth A et al (2004) Improving care for the ventilated patient. Jt Comm J Qual Saf 30:195–204
63. Hall RI, Rocker GM, Murray D (2004) Simple changes can improve conduct of end-of-life care in the intensive care unit. Can J Anaesth 51:631–636
64. Lee MJ, Gershengorn HB, Dinkels M et al (2012) Checklist for lung injury prevention (CLIP): A pilot study on implementation across multiple hospitals and multiple clinical areas. Am J Respir Crit Care Med 185:A6567 (abst)
65. Harrahill M, Bartkus E (1990) Preparing the trauma patient for transfer. J Emerg Nurs 16:25–28
66. Djogovic D, Green R, Keyes R et al (2012) Canadian Association of Emergency Physicians sepsis treatment checklist: optimizing sepsis care in Canadian emergency departments. CJEM 14:36–39
67. Wolff AM, Taylor SA, McCabe JF (2004) Using checklists and reminders in clinical pathways to improve hospital inpatient care. Med J Aust 181:428–431
68. World Health Organization (2009) Patient care checklist. Available at: http://www.who.int/csr/resources/publications/swineflu/ah1n1_checklist.pdf Accessed Nov 2013