Critical Illness on General Floors: Reliability Plus Redundancy Equals Resilience?*

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Cancer is a leading cause of death globally with a growing number of new cases expected to reach 23.6 million per year by 2030 (1). The breadth of aggressive treatments and the quality of outcomes for patients with cancer continue to improve with impressive pace. Whereas the diagnosis of incurable cancer once meant poor long-term survival or even imminent death, it now prompts individualized treatment regimes targeting specific tumor types aiming to achieve remission or halting disease progression and ultimately extend patient's lives for many months or even years. These patients are prone to both malignancy and treatment-related complications often resulting in critical illness. Historically, this has presented both prognostic and ethical dilemmas to critical care physicians who have lacked good quality evidence to guide the management of this important patient group. However, an evidence base is now accumulating, with many data showing comparable outcomes for patients with cancer admitted to critical care compared with those without cancer (2, 3).

In this issue of *Critical Care Medicine*, Lee et al (4) present an observational data on both short- and long-term outcomes for patients with cancer who deteriorate on the general ward, trigger a review by the medical emergency team (MET), and are subsequently admitted to critical care. They found that initiation of the MET within 1.5 hours following the patient's deterioration on the ward resulted in better short- and long-term survival compared with late initiation of the MET after more than 1.5 hours. The 1.5-hour threshold used to define early and late MET initiation is based on a previous study by Song et al (5) from the same institution. Early bedside attendance by appropriately skilled teams is desirable for any deteriorating patient, but it is difficult to conceive that an interval of more than 90 minutes will pose a heavy influence on long-term survival.

Patients with cancer often receive a combination of complex therapies over many weeks, usually necessitating prolonged hospital admission. Long-term prognoses are dependent on a multitude of factors, including tissue diagnosis, disease staging, adequacy of response to initial treatment, and preexisting comorbidities. When these patients become critically ill, medical staff need time to make adequate clinical assessments and formulate appropriate management plans. We suggest this process is time consuming in patients whose long-term outcome is suspected to be poor and/or where treatment limitations are being considered. The results of this study are therefore heavily vulnerable to selection bias. This is illustrated in the data by a greater prevalence of hematological malignancy, neutropenia, documented infection, need for cardiovascular support, and higher illness severity scores at ICU admission for those in the late MET initiation group.

The purpose of METs is to expedite critical care expertise to the bedside of deteriorating patients to ensure early decisions and interventions are made. Data concerning specific populations of patients with cancer are scarce; however, Tirkkonen et al (6) reported the presence of cancer being an independent predictor for delay in MET activation in a small single-centered study in Finland. Other studies have focused on the time interval between recognition of physiological deterioration and admission to the ICU. In a large cross-sectional study, Chalfin et al (7) demonstrated increased ICU and hospital mortality for patients delayed for more than 6 hours for their transfer between the emergency department and ICU. An international multicentered study assessing the time between patient's raised early warning scores and admission to ICU—the "score to door time"—found this to be a median of 4 hours 10 minutes (8). Like Lee et al (4), the authors of this study found increased score to door times was associated with higher Acute Physiology and Chronic Health Evaluation II scores at ICU admission. Lee et al (4) have focused on a shorter alternative time interval of 90 minutes from a patient's deterioration to MET initiation for which there is very little published adult data for comparison. A single-centered study from Brazil found a delay of more than 30 minutes from documented MET criteria to actual MET review was associated with higher 30-day mortality for all hospitalized patients over a 12-month period (9). This study also found a higher need for critical care admission among those receiving delayed MET review, but the authors highlighted the complexity and

*See also p. 1439.

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subjective nature of the likely causes for delay in initiating a MET review. Lee et al's (4) benchmark of 90 minutes is therefore currently aspirational in its appliance to other institutions and patient populations, but it is certainly one worthy of further investigation in future studies.

In order to achieve Lee et al's (4) fast activation times in a reliable fashion in hospitals throughout the world, current systems are clearly insufficient. Even in the present article more than half of the patients had to wait for longer than 90 minutes for a response. High-reliability industries have therefore found technological solutions to assure resilience. One of the underlying principles of safety is called "modular redundancy" (10). The principle of modular redundancy assures that safety critical steps are never guaranteed by only a single mechanism but simultaneously by at least two independent ones. To this effect, Boeing and Airbus planes will have triple and quadruple redundant electronic systems (11). National Aeronautics and Space Administration was equally concerned about error, and its first missions all had two computer systems that had been programed separately. In this sense, active surveillance of patients by their own team and an independent system of scrutiny seem crucial to achieve the same reliability and resilience.

The redundant system could in theory be human: MET can undertake regular active surveillance of clinical areas and search systematically for patients with physiological abnormalities who have been overlooked. Technological systems can serve the same purpose and achieve reliable automated surveillance and notification of responders (12–14).

Faster care is likely to save more lives in time-critical conditions. Safe systems need to be redundant. Given that the principle is long established in technology-driven industries, it seems counterintuitive that it has not been used more in medicine. The article by Lee et al (4) would suggest that now is a good time to close this gap in research and practice.

REFERENCES

1. International Agency for Research on Cancer and Cancer Research UK: World Cancer Fact Sheet. London, UK, Cancer Research UK, 2014
2. Taccone FS, Artigas AA, Sprung CL, et al: Characteristics and outcomes of cancer patients in European ICUs. *Crit Care* 2009; 13:R15
3. van Vliet M, Verburg IW, van den Boogaard M, et al: Trends in admission prevalence, illness severity and survival of haematological patients treated in Dutch intensive care units. *Intensive Care Med* 2014; 40:1275–1284
4. Lee D-S, Suh GY, Ryu J-A, et al: Effect of Early Intervention on Long-Term Outcomes of Critically Ill Cancer Patients Admitted to ICUs. *Crit Care Med* 2015; 43:1439–1448
5. Song JU, Suh GY, Park HY, et al: Early intervention on the outcomes in critically ill cancer patients admitted to intensive care units. *Intensive Care Med* 2012; 38:1505–1513
6. Tirkkonen J, Ylä-Mattila J, Olkkola KT, et al: Factors associated with delayed activation of medical emergency team and excess mortality: An Utstein-style analysis. *Resuscitation* 2013; 84:173–178
7. Chalfin DB, Trzeciak S, Likourezos A, et al; DELAY-ED study group: Impact of delayed transfer of critically ill patients from the emergency department to the intensive care unit. *Crit Care Med* 2007; 35:1477–1483
8. Oglesby KJ, Durham L, Welch J, et al: 'Score to Door Time', a benchmarking tool for rapid response systems: A pilot multi-centre service evaluation. *Crit Care* 2011; 15:R180
9. Boniatti MM, Azzolini N, Viana MV, et al: Delayed medical emergency team calls and associated outcomes. *Crit Care Med* 2014; 42:26–30
10. Flehinger BJ: Reliability improvement through redundancy at various system levels. *IBM J Res Dev* 1958; 2:148–158
11. Papadopoulos GM: Redundancy Management of Synchronous and Asynchronous Systems, Fault Tolerant Hardware/Software Architecture for Flight Critical Functions. AGARD-LS-143. 1985
12. Buist MD, Moore GE, Bernard SA, et al: Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: Preliminary study. *BMJ* 2002; 324:387–390
13. Bellomo R, Ackerman M, Bailey M, et al; Vital Signs to Identify, Target, and Assess Level of Care Study (VITAL Care Study) Investigators: A controlled trial of electronic automated advisory vital signs monitoring in general hospital wards. *Crit Care Med* 2012; 40:2349–2361
14. Schmidt PE, Meredith P, Prytherch DR, et al: Impact of introducing an electronic physiological surveillance system on hospital mortality. *BMJ Qual Saf* 2015; 24:10–20