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A Systematic Approach to Manage Clinical Deterioration on Inpatient Units in the Health Care System

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Colleen H. Swartz, Student

Dr. Patricia B. Howard, Advisor

DNP Capstone Report

A Systematic Approach to Manage Clinical Deterioration on Inpatient Units in the Health Care System

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College of Nursing

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Deterioration is defined in the Webster dictionary http://www.merriam-webster.com/dictionary/deterioration as "falling from a higher to lower level in quality, character or vitality." Clinical deterioration may be defined as the physiological decompensation that occurs as a patient experiences worsening of a preexisting serious condition or acute onset of a serious physiologic disturbance. The early identification, recognition and acknowledgement of clinical deterioration of patients in the acute care setting are a matter of serious concern. A need exists to prospectively characterize the etiology of physiologic deterioration as well as the temporal events leading to the occurrence of deterioration. Integration of an automated early warning system could narrow the gap between onset of clinical deterioration and recognition of the signs of deterioration by care providers.

Buist (2008) defines a concept of "clinical futile cycles" which occur when a flurry of clinical activity is directed at the patient, but little of the activity relieves the dire circumstances of the patient. The clinical futile cycle in the case of clinical deterioration prompts a different approach to care delivery to dissipate the existing barriers and ensure more proximity between onset of clinical recognition of deterioration episodes and the application of appropriate interventions. The timeliness of recognition of deterioration may be compounded by the incidence of increased frequency of junior and inexperienced physician and nursing staff attending the patients who may be at risk of deterioration during periods where the infrastructure is not in place to allow a timely response to prevail.

Many factors have coalesced to demand a renewed and innovative approach to the existing care delivery model, especially in academic medical centers. For decades, the care model in academic centers has largely been predicated on medical resident manpower. Contemporary changes in the teaching model of physician preparation, acuity and complexity on the inpatient units, a laser focus on quality and safety in hospital settings and increasing demands on nursing staff as knowledge workers have created an environment particularly suited to innovative countermeasures and improvements in the model of care delivery.

Several layers of the care model should be examined in order to devise an approach suitable to meet the current dynamic issues present in our health care system. A critical look at all factors including structure, process and outcome may provide the best opportunity for creating models of care that can be tested, evaluated and improved in an equally dynamic fashion. Each of the factors has been examined to propose one iteration of a potential approach to improving the care model. Continued innovation and evaluation should be undertaken to encourage further evolution of this work.

Overview of Capstone Project Paper

In order to logically order the overview, Donabedian's (1983) Structure-Process-Outcome Paradigm was used as the conceptual framework. The structure-process-outcome model has been applied and integrated in evaluation of health care delivery systems for decades since originally published. Structure is viewed generally as the policies, standards, guidelines and infrastructure that provide an environment for growth and evolution of the care model as it relates to acknowledgement and response to deterioration. Process is typically viewed as those activities leading to outcomes. Outcomes represent the product or deliverable from processes conducted in the given structure. The structure-process-outcome paradigm can be considered as a sequential process with a causal relationship. Framing the work using this conceptual model may allow others to replicate or modify the work in order to provide an approach of continuous improvement in system responsiveness. The Capstone report consists of three papers that are organized around this framework. A brief overview of the papers follows.

The Missing Link:
Using Nurse Practitioners to Accelerate the Quality/Safety Value Proposition - A Potential Medicare Demonstration Project

The transformation of health care delivery in the United States is accelerating at unbelievable speed. The acceleration is a result of many variables including health care reform as well as the covariation occurring with adjustments in regulations related to resident work hours. The evolving care delivery model has exposed vulnerability in the health system, specifically in academic medical centers of the United States. Academic medical centers have established a care delivery model grounded and predicated in resident presence and performance. With changes in resident work expectations and reduced time spent in hospitals, an urgent need exists to evaluate and recreate a model of care that produces quality outcomes in an efficient, service driven organization. One potential care model that would stabilize organizations is infusion of advanced nurse practitioners (APNs) with the expanded skills and knowledge to instill practice continuity in the critical care environment.

The first article of the report develops the guiding principles for a Medicare demonstration project. The project is proposed as a mechanism for funding an APN expanded role and alteration in the care delivery model. Formative and summative evaluation of impact of such an expanded practice role is included in the proposed project. An evolved partnership between the advanced practice nurse and physician will serve to fill some of the gap currently existing in the delivery system of today. As the complexity and acuity of the patients in the hospital escalates, innovation is demanded to ensure a care model that will foster achievement of the quality outcomes expected and deserved.

Recognition of Clinical Deterioration - A Systematic Literature Review

The second article is related to process work of recognizing clinical deterioration and the defining characteristics of successful models where deterioration has been acknowledged as disruptive to the system of care and deleterious to patient outcome. Recognition of clinical deterioration can be termed a “critical success factor” in every care delivery model. A systematic review of the literature related to recognition of

clinical deterioration could lead to focus areas for further research in order to dissect and improve the essential skill of recognition of the "physiologic abnormalities of disease" and bring to bear, in a more timely fashion, the necessary interventions to blunt deterioration and, ultimately, improve clinical outcomes.

The inpatient care unit in 2010 is overflowing with complex, acutely ill patients with the potential at any time for physiological instability. When destabilization occurs, and clinical deterioration becomes evident, the system responsiveness must be fail safe. In order to create a system of precise, non-subjective triggering of rescue systems, attention must be given to process development that automates the triggering. The review of the literature clearly demonstrates knowledge of the deterioration is not the primary issue. The actionable data is present. However, the translation, interpretation and willingness to appropriately execute by the front line provider presents a potential barrier to a precision system. Further investigation of behavioral issues as well as the potential to leverage technology could assist in breaking the "clinical futile cycle" of care and expedite the necessary resources to the patient.

Utility of an Automated Early Warning System to Accelerate Recognition of Clinical Deterioration

The final article of the capstone report is related to a systems intervention that could affect the outcome of patients experiencing clinical deterioration. A quasi-experimental study was conducted with the intervention of implementation of an early warning system based on physiologic criteria imbedded in the electronic health record. The specific aims of the study were to describe the demographic and clinical characteristics of the patients who experience clinical deterioration, compare timeliness of recognition of clinical deterioration after implementation of an early warning system using physiologic variable from the electronic medical record to trigger response and to analyze key outcomes impacted by system activation.

The Missing Link:
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Abstract

The transformation of health care delivery in the United States is accelerating at unbelievable speed. The acceleration is a result of many variables including health care reform as well as the covariation occurring with adjustments in regulations related to resident work hours. The evolving care delivery model has exposed a vulnerability of the health system, specifically in academic medical centers of the United States. Academic medical centers have established a care delivery model grounded and predicated in resident presence and performance. With changes in resident work expectations and reduced time spent in hospitals, an urgent need exists to evaluate and recreate a model of care that produces quality outcomes in an efficient, service driven organization. One potential care model that would stabilize organizations is infusion of APNs with the expanded skills and knowledge to instill practice continuity in the critical care environment. A Medicare demonstration project is proposed for funding an APN expanded role and alteration in the care delivery model. Formative and summative evaluation and impact of such an expanded practice role is included in the proposed project. An evolved partnership between the advanced practice nurse and physician will serve to fill some of the gap currently existing in the delivery system of today. As the complexity and acuity of the patients in the hospital escalates, innovation is demanded to ensure a care model that will foster achievement of the quality outcomes expected and deserved.

The Missing Link:

Using Nurse Practitioners to Accelerate the Quality/Safety Value Proposition - A Potential Medicare Demonstration Project

In 1965, Congress established the Medicare program. From the beginning, Congress recognized that quality of care in an institution was enhanced by educational programs and that the cost of those programs would be subsidized, to some extent, by Medicare funding. From 1965 until the mid 1980s, Medicare paid its share of Direct Graduate Medical Education (DGME) costs based on "Medicare allowable" costs submitted by hospitals on their individual cost reports. Medicare altered its payment strategy in 1986 with the Consolidated Omnibus Budget Reconciliation Act (COBRA) that uncoupled the relationship between direct costs and DGME payments. The program included audits of a hospital's cost report to determine the cost of each resident in the DGME program and limited the number of years for fully supporting its share of residency training. (https://www.aamc.org/advocacy/gme/71152/gme_gme0001.html).

The Balanced Budget Act of 1997 brought more changes to the DGME payment schedule. (http://www.cogme.gov/resource_bba.htm). For example, limits were placed on the number of full-time equivalent residents that hospitals could count for DGME payment and required residents to be counted using a three-year rolling average methodology. In 2009, payment was based upon hospital DGME costs in 1984, updated by application of an inflation factor, and then modified based on program share of total hospital inpatient days. A slightly higher payment exists for primary care residencies versus subspecialties (Younce, E., McDowell, S., personal communication, October 2009).

Public policy concerning the financing of graduate medical education must be clearly articulated, demonstrate exacting goals and objectives, and rigorous evaluation of outcomes related to resident education. Obviously, many academic medical centers have based the care delivery model upon resident role integration and influence regarding health care quality and safety. Few issues in health care delivery have generated as much heated debate as regulation of resident work hours. The United States Health Care Delivery Systems in academic medical centers have relied heavily on resident driven quality outcomes and safety infused processes for decades. However, the 2003 change in

resident work hours has created a chasm in care that must be addressed in order to continue to drive safe, effective and quality care environments across the United States. The purpose of this paper is to outline the salient quality and outcome impacts of the changing care delivery model and propose a potential alteration in the model to improve care quality, efficiency and service in the inpatient environment of an academic medical center.

Statement of the Issue

On July 1, 2003, the American Council of Graduate Medical Education (ACGME) imposed universal regulation of resident work hours. (http://www.acgme.org/acWebsite/newsRoom/newsRm_dutyHours.asp). The regulation limited total averaged weekly work hours to 80 hours based on duration of any individual shift total of 30 hours (defined as 24 hours plus 6 hours for hand off) time-off between shifts of 10 hours, and at least four days off over four weeks. The greatest impetus for the United States regulation was a direct concern for patient safety that was reinforced and promulgated by an Institute of Medicine (IOM) report as well as concern that external regulation could occur if some boundaries were not established (Lipsett, 2009).

The IOM released a report in 2008 which recommended even further measures be instituted to ensure that hospitals would provide safer conditions for patients and trainees while maintaining rigorous teaching programs. The new measures were designed to focus on alleviating fatigue and loss of sleep for trainees, increase supervision by more senior physicians, improve processes for hand offs/ transferring of responsibility from one provider to another, and increase the rigor of enforcement of the regulations established by the ACGME (Iglehart, 2008). Additional measures under consideration included a provision that (1) any shift for a resident that was over sixteen hours must include a five hour, uninterrupted period of continuous sleep between ten p.m. and eight a.m.; and (2) there would be no work or on call duty during the uninterrupted period. If implemented, the measure would interrupt the resident's ability to admit new patients after sixteen hours on duty, and night float or night duty would not be permitted to exceed four consecutive nights to be followed by a minimum of forty-eight continuous hours off duty (Blanchard, Meltzer, & Polonsky, 2009).

Clearly, the evolution of regulating resident work hours has created a gap in care delivery for patients, especially the most complex, critically ill patients found in academic medical centers. As noted, many academic medical centers have predicated the care delivery model on the foundational construct of resident influence, availability and decision making. Yet the new regulation limit on residents' work means that other providers must provide the service and/or systems must be adjusted to ensure achievement of quality and safety objectives with the system. Intense evaluation of work flow, provider performance and gap closure of this change is essential to maintain system integrity. Since the regulatory imposition of the work hour standards in 2003, several scientific studies have been generated to evaluate the impact on the clinical conduct of care (Bhavsar et al., 2007; Lipsett, 2009; Morrison, Wyatt, & Carrick, 2009; Nuckols, Bhattacharya, Wolman, Ulmer, & Escarce, 2009; Prasad et al., 2009; Shetty & Bhattacharya, 2007; Volpp, Rosen, Rosenbaum, Romano, Even-Shoshan, Canamucio et al., 2007a; Volpp, Rosen, Rosenbaum, Romano, Even-Shoshan, Wang et al., 2007b). The significance of the issue cannot be underestimated and it must be clearly defined.

Significance of the Issue

Issue significance related to imposition of resident work hour regulation can be evaluated from a clinical perspective as well as an economic one. Several studies report attempts to quantify the impact of adjustment in resident work hours on clinical outcomes. For example, Prasad et al., (2009) evaluated outcome impact on 230,151 adult patients admitted to 104 different intensive care units at forty hospitals. The primary outcome was in-hospital mortality and a secondary outcome was intensive care unit mortality. No significant differences in mortality trends between hospitals were found post implementation of ACGME resident work hour's regulations. Additional studies report similar findings with either no change or a relatively small mortality improvement in medical and surgical patients in teaching hospitals, compared with nonteaching hospitals (Volpp, Rosen, Rosenbaum, Romano, Even-Shoshan, Canamucio et al., 2007a; Volpp, Rosen, Rosenbaum, Romano, Even-Shoshan, Wang et al., 2007b).

Interestingly, Shetty and Bhattacharya (2007) found that regulatory changes were associated with improved outcomes in medical patients but not in surgical patients.

Several explanations were offered regarding this difference including a smaller sample size for surgical patients, limited adjustment in surgical residency work patterns, reduction in available surgical providers if no net increase in surgical residents occurred and counterbalancing of errors due to fatigue with problems related to transfer of care.

A study regarding the impact of change in residency work hours on the mortality and morbidity in trauma patients was conducted by Morrison et al., (2009). The study results do not permit one to conclude the regulation of resident work hours has resulted in improved trauma care delivery. However, one can confidently conclude there has been no significant erosion in trauma care because of the adjusted resident work hours. In addition, there was a more positive impact on outcomes of inpatient cardiology patients with the diagnosis of acute coronary syndrome. The study of 1,003 patients demonstrated implementation of the ACGME regulations was associated with improved quality of care and efficiency (Bhavsar et al., 2007).

Not only has the clinical sequelae associated with the ACGME regulations been studied, the economic impact has also been closely evaluated. Nuckols et al., (2009) evaluated the cost implications of reduced work hours and workloads for resident physicians. Specifically, the incremental changes proposed by the IOM were evaluated for potential economic impact related to transferring excess work from residents to substitute providers. Annual labor costs were estimated to be $1.6 billion across all ACGME accredited programs. Net costs per admission were forecasted at $99 to $183 for major teaching hospitals and from $17 to $266 for society. Clearly, implementation of the additional regulations would be quite costly and its effectiveness unclear. The confusion in impact on outcome related to the regulatory changes contributes to the gap that has been created both clinically and economically.

Adjustment of the Care Delivery Model

Several key issues and processes contribute to the care delivery gap and need for care model adjustment that has been accelerated by the imposition of resident regulatory work hours. Many academic medical centers responded early and completely to the change in resident work hours and impact on the care model by identifying impact on care processes and filling the gaps with substitute advanced practitioner providers. Issues

created by the regulatory change included increased hand offs and transferring of responsibility of care from provider to provider resulting in potential safety risk and loss of continuity of care. Other issues included: (1) increased episodes of cross coverage by trainees for patients who have limited knowledge regarding plan of care or care risk; (2) more residents assigned to critical care areas, leaving other areas thinly covered; (3) the impact on senior physician responsibilities and increased dissatisfaction with increased requirements for in house availability; and (4) heavier reliance on nursing staff to provide continuity of care during hand offs and transitions.

Additionally, Shetty and Bhattacharya (2007) noted another potential gap. They cautioned that the regulations' long term effect resulting from shifting care from inexperienced residents to more experienced providers like hospitalists might precipitate a more long term impact that would be deleterious if resident physicians did not experience adequate skill acquisition during residency and subsequently increase their error rate post residency. Further study will be required to quantify this impact.

Adjusting the care delivery model must also address the contextual variation in the clinical posture of inpatients found in the academic medical center of today. Over 100 years ago, Sir William Osler noted, "If you listen carefully to the patient they will tell you the diagnosis" and "Patients do not die of their disease, they die of the physiologic abnormalities of their disease" (Bean, 1950). Even in the earlier years of clinical practice, the need to assimilate key messages signaling the care provider to take action was a clear and basic tenet of quality patient care. Patient safety has become an area of pinpoint focus over the preceding decade. The evolution of inpatient care has also become increasingly complex, chaotic and predicated on knowledge and mastery of multiple system signals in order to provide the highest quality care possible. Recognition of clinical deterioration can be termed a "critical success factor" in every care delivery model. As critical care resources become more constrained and allocated to the most critical of patients, more patients are being shifted to venues with limited monitoring capability or venues where no continuous physiologic monitoring occurs at all, except by application of clinical gestalt by the care providers based on data retrieved manually at one, two or even four hour intervals. Clearly, a compelling need exists for adjustment of the care delivery model including constructs of the providers of care delivery as well as

the infrastructure and processes of care deeply imbedded in the system to support the high acuity patients found in our complex health care system.

Findings of all these and other studies (Buist, 2008; Goldhill, White, & Sumner, 1999; Hillman et al., 2001) have prompted a sense of urgency in Academic Medical Centers to address the metamorphosis of the care delivery model in light of the regulatory changes and changing system's complexity and patient acuity. Identification and infusion of care providers who can provide a constancy of care, high quality outcome, safe process in hand off continuity and critical thinking given the increasing complexity and acuity of inpatients, is imperative in order to achieve clinical and financial objectives. The infusion of Advanced Practice Nurses (APNs) is one solution that has been adopted by many facilities and is heavily under consideration by others. However, the APNs must possess the essential skill set required to care for the increasingly complex and, often, critically ill inpatient. In addition, automation of triggering systems to enhance the infrastructure of complex organizations will provide more effective clinical management of the increasingly complex, high acuity patients.

Conceptual Framework

Kingdon's (1984) policy streams approach was the conceptual framework used to analyze the issue. Kingdon conceptualizes policy making as three largely unrelated streams. First, a problem stream consisting of information about real world problems and effects of past governmental interventions is identified. Second, a policy stream is established with researchers, advocates, and other specialists who will analyze problems and formulate alternatives. Third, a political stream is designed for elections, legislative leadership contests, etc. Kingdon describes how the interactions of the three-policy streams influences major policy reform when a window of opportunity opens, joins, and enhances the three streams in response to a recognized problem. The policy community defines the alternative and the political leadership deems the policy reform necessary to be legislated.

The problem stream regarding the crises in the care delivery model and the urgent need for solutions has been detailed in the preceding text. The existing format for Medicare funding of physician education and the gaps in care created by ACGME

regulation has resulted in a need to reevaluate the care delivery model and the impact on health care delivery. The policy stream is represented by a number of academic medical centers and providers which have enacted many and varied solutions to fill the gap created by the current state. One potential alternative is presented in this manuscript. The political stream is represented by existing Medicare funding and legislation detailing physician trainee funding and a potential alternative that could be influenced through Medicare regulation to expand the funding for critical care APN "residencies."

Key Stakeholders

There are many stakeholders in this emotionally charged issue. For example, redirection of Medicare funding to APN "trainees" could create some issues for residency programs and, even, more senior supervising physicians. Perceived loss of control or influence by the physician community certainly leads to a passionate voice within the policy stream. Nursing leaders and APNs certainly are key stakeholders as well as professional nurses choosing to practice in the inpatient arena. Indeed, in the current milieu coexisting with health care reform changes, dialogue continues to embrace and promote the integration of APNs in the care delivery model. The critical window of opportunity seems to be wide open at this time and a historical step could be taken to advance the role of the APN in the care delivery model. Acknowledgement of this integration and subsidization of the role by Medicare could be a substantive construct in the forward progression of post APN education with a critical care residency. Other stakeholders include the patients, of course, who have come to expect safe care processes and quality outcomes. The financial arm of all academic medical centers is clearly stakeholders because of the potential financial impact filling the gap and the economics of operations as well as revenue cycle implications. Politicians will certainly have a stake in the evolution of the academic medical center in their home areas. Other stakeholders include other care providers, non-academic medical centers, regulatory agencies and infrastructure support suppliers such as electronic medical record vendors.

Political Considerations

Other factors exist which could be facilitative or limiting in terms of the influence on the advancement of Medicare funded post APN fellowships in critical care. The political perceptions of the medical community have been noted. Clearly, the positioning and input of the medical staff could be facilitative or limiting based on posture assumed. More importantly, the adoption of partnerships that are deep and broad in scope between the APN and the physician are essential for promoting the care delivery model that is proposed. The broadening scope and critical nature of the APN's influence on the conduct of care could be viewed as encroachment on medical practice. Therefore, the integration must be handled thoughtfully and deliberately in order to ensure a patient centered approach and quality outcomes.

Certainly the economic influence is an important factor to consider in the evolution of the proposed APN model. The presence of the APN and potential displacement of previously resident governed activities could have either a negative or a positive impact on contribution margin. A careful financial model must be developed to adequately forecast the impact as well as cost benefit analysis. One aspect to consider is the impact of the changing model on the patient. The ultimate consumer of services is very sensitive to presence of care provider. In one study, the majority of patients agreed one of their team doctors should be in the hospital at all times and they felt safer when one of their team doctors was in the hospital overnight (Fletcher et al., 2008).

Potential Policy Alternatives

Several alternatives exist to filling the gap with APNs. Many facilities have elected to increase the number of residents in the academic medical center. However, this has not proven to provide adequate coverage and has, in some cases, exacerbated the number of hand offs in care that could lead to more errors, delays in care, or protracted patient length of stay. Without the increase in number of residents, the use of cross covering systems of care could result thus producing the same results as above. Allocation of residency slots also presents a specific conundrum in terms of need manifested by underserved areas. For instance, the northeastern section of the country continues to have increased allocation of residency slots but the most underserved areas

exist in the southern sections of the country. In addition, should health reform continue its legislative march, many issues could persist and even experience exacerbation. The current movement suggests pulling in uninsured Americans –currently estimated at forty seven million. With an already stretched and bending health care system, where are the providers who would take on this additional burden? In addition to APNs, other advanced practitioners currently recognized are Physician Assistants. Regardless, the scope of practice must be carefully evaluated for each level of advanced practitioner to ensure a match between clinical need and provider skill set.

Other policy alternatives might include avoidance of the resident work hour regulations that then increases risk of sanction and fines, and potential ultimate loss of ACGME accreditation for residency program and loss of Medicare funding. Academic medical centers could choose to deploy the care delivery model and subsidize the post APN training in order to avail the more experienced provider within the care delivery model. Other alternatives could include careful scrutiny of resident work flow and assignment of non health care providers to pick up those work product items that are clerical in nature in order to increase the efficiency of the resident.

Certainly other iterations of care models could be considered with variant levels of advanced practitioner integration. The morphology of the care model must be carefully considered in order to eliminate error, increase continuity and provide quality, efficient care. Other sources of funding could also be investigated to subsidize the incremental training.

Recommended Policy Option

The recommended policy option is to petition Medicare to fund a Demonstration project that subsidized Direct Graduate Nursing Education, specifically a post APN fellowship of one to two years in critical care. The specific focus on critical care is essential due to the increasing complexity and acuity of inpatients with key decision points evident in the critical care phase of care. Currently, education programs for APNs do not prepare the nurse practitioner in the sophisticated skill required for critical care of patients in the academic medical center. Not only is the care complicated, but also the systems of care continue to evolve in complexity and technology based solutions evolve

with the confluence of the electronic medical record. Specific outcomes would be monitored in the demonstration project to include errors, length of stay in the critical care unit, resident and nursing staff satisfaction, patient satisfaction, financial impact and achievement of specific quality measures.

Strategies for Moving Forward

Key political lobbyists have been identified to begin discussion of the possibility of a demonstration project. A key strategist has been identified to present the value proposition for evaluation, recommendation and specific action items to carry forward. The Centers for Medicare and Medicaid Services (CMS) sponsors a number of innovative demonstration projects to test and measure the effect of potential program changes. The demonstration projects study areas such as impact of new methods of service delivery, coverage of new types of services and new payment approaches (http://www.cms.hhs.gov/DemoProjectsEvalRpts/01). The intent of CMS is to validate research findings and findings from other demonstration projects and monitor the effectiveness of the programs. Several demonstration projects are currently open including ambulatory practice integration, imaging and electronic health records.

Obviously, a key strategy is to promote the "appointment" of the key topic of interest as a priority for the political agenda. Understanding key priorities is an important aspect of developing strategy. Typically, key initiatives are identified and surface through congressional discussion. Once identified as potential for CMS demonstration project, a set of criteria is developed to announce "the call" for projects with a grading rubric published. The grading is then performed by career bureaucrats and decisions are made regarding funding. Given this process, a key is to understand the "touch points" of relevant political discussion.

Relevancy to current discussions on the political agenda could ensure successful assignment of demonstration project status. A key strategist in Medicare and Medicaid projects advises that currently an emphasis and priority be set on horizontal linkages and affiliations that influence the continuum of care. (Birdwhistell, M., personal communication, 2009). The horizontal linkages may be achieved through a proposal that integrates regional networking and balances the project initiatives such as education and

care delivery. Integration of these two concepts is critical for public funding as well as the concept of filling in the care delivery gap in medically underserved areas such as the rural health care delivery system evident in Kentucky.

Further strategy will involve leveraging a former CMS Director/Administrator and a current CMS Administrator where relationships exist with key leaders within UK HealthCare. A one page executive summary of the demonstration project proposal (Appendix A) integrating these key concepts will be circulated for feedback and "technical assistance" in writing construct to further promote the key concepts. Developing a CMS demonstration project may entail a deliberate, lengthy journey. Thus, a contingency plan must be developed in order to fund the potential application of the strategy or to bridge the development of the process during formative stages.

A more specific tactical approach will serve to be useful and provide some specificity around action items to realize the strategic agenda. A three-step approach will be utilized to promote the possible success of the implementation of the demonstration project:

1. Deliberately scan current CMS Demonstration projects to determine potential applicability and "goodness of fit" for the proposed project. An existing open call for demonstration projects could provide a topic/venue appropriate to mold the proposal and potentially gain funding.
2. Use current lobbyists and strategists to advocate with CMS for additional demonstration projects under current authority to solicit proposals from academic health centers and Colleges of Nursing. Perhaps the realization that the powerful partnership between these two formidable forces could result in some needed solutions for filling the existing gap of providers, especially in the inpatient hospital setting.
3. Advocate to Congress for additional Demonstration authority housed within CMS. The process to achieve this advocacy will be to reference the specific points within the proposal that support the value proposition. Specifically the alliance between strategic partners such as the College of Nursing and the Academic Health Center that could ultimately increase quality and decrease cost: A key construct for measurement by the demonstration projects issued. Another

tactic would be to present the approach to Committees of jurisdiction such as the House Ways and Means Committee who has jurisdiction over Medicare and House Appropriations. Presentation of the approach could simultaneously be pursued with the Senate Health, Education, Labor and Pensions Committee and Senate Finance Committee that have direct or indirect authority over Medicare.

A potential contingency plan has been considered to move the proposal forward, however, to include a collaborative partnership with the College of Nursing to develop curriculum, submit nurse training costs for addition to cost report and subsidization of approximately thirty percent of salary structure, then subsidization from operational funds by demonstrating positive contribution margin impact of a new care delivery model. Exploration of other strategies include staying current with and taking advantage of potential funds available through health care reform platform and potential expansion and increased funding for graduate nursing education. Additional data should be gathered from other academic medical centers that have made or are making the transition from a resident predicated care delivery model to one predicated more heavily on infusion of APNs. Several medical centers exist who have changed the philosophy of care delivery to providing care using APNs, then interdigitating resident education on top of the model, enhancing the model where appropriate to achieve training requirements (Iglehart, 2008; Nuckols et al., 2009).

Fiscal Impact

Nuckols et al., (2009) recently described the cost implications of further, more restrictive regulations of resident work hours. The additional recommendations would result in $1.6 billion of substitute labor. With the use of additional residents instead of substitute providers, at least 8 percent more residency positions would be required, costing up to $1.7 billion annually. The 2003 reforms were estimated to have cost $1.2 billion. The cost per hospital is anticipated at $3.2 million annually and the cost per admission is forecasted at $141. The recommended changes have been noted to be cost saving for society by the reduction of medical errors, but cost generating for academic medical centers makes the cost benefit analysis complicated. The authors suggested

alternative potential strategies to mitigate the financial impact. The alternatives include increasing the workload of faculty physicians, increasing charges to patients, permissive reduction in operating margin, reduction of services, improving efficiency, permissive decline in quality or securing some other mechanisms for subsidization.

Unintended Consequences

Unintended consequences of adopting the proposed strategy should be given careful thought and consideration. Adjustment of the care delivery model could exacerbate the potential reduced quality of physician education, producing less prepared physicians who could experience higher rates of error post residency completion. The impact on clinical care long term must be carefully considered. The cultural transformation of a care delivery model predicated on APN practice with interdigitated resident education will require double time work on communication, role definition, and assignment of responsibility and accountability measures. An adversarial relationship between providers could evolve which would create a negative impact on conduct of clinical care. Patient education would need to be clear and crisp regarding clinical providers and responsibilities. Failed expectations of the inpatient experience could create a problem with service utilization and volume as well as adequacy of clinical care.

As training of critical care based APNs is implemented, care should be exercised regarding potential competition with physician trainees for key procedures, decision making and similar care delivery situations. Again, clear definitions of roles and expectations as well as allocation of key aspects of training opportunities must be observed. Clear expectations and negotiation with payers regarding reimbursement models will require focused attention to avoid potential reduction in revenue stream related to non-physician providers that has been a tenet of many payers during the past decades.

Implementation and Enforcement Issues

Many issues exist with implementation and enforcement of new models. In this instance, the cultural transformation associated with a change in the care delivery model will require very careful, deliberate and exhaustive education of all providers within the

system of care. Clear roles and responsibilities must be outlined and reinforced with constant coaching and problem solving by physician and nurse leaders. The deeper integration of an interdisciplinary team will require increasing levels of communication among providers. The training issues related to post APN critical care training will also have to be clearly outlined and integration of the senior physicians as instructors will be essential to success so the clear cognitive skill as well as physical skill are taught, reinforced and deeply engrained in the critical care APN. Demonstrating cost benefit and creating a financial model that adequately demonstrates and quantifies the APN's impact on critical care will be essential to evaluate the financial impact of the model. Exacting quality measures will also be essential to demonstrate the quality impact of the transformed care delivery model. Role confusion seems to present the most pressing challenge during implementation as well as enforcement. Senior teams of physician and nurse leaders will need to assume responsibility for model supervision and demonstrate support, expectations, and evaluative measures for success. The enforcement of the model should also be done in a fashion that results in academic productivity in model analysis and dissemination of impact on care. Sustaining the model will require evaluation plans including pilot studies designed to address the qualitative and quantitative aspects of quality, economic and service impact in the health care delivery system.

Conclusion

The transformation of health care delivery in the United States is accelerating at unbelievable speed. The regulatory changes for resident education currently taking place combined with the potential for further restriction of the medical resident model has accelerated the need for intense scrutiny of our health care delivery model in general. The regulations have likely improved some aspect of resident performance, and at the same time have exposed a vulnerability of the health system, specifically in the academic medical center of today. Often, the academic medical center has established a care delivery model grounded and predicated in resident presence and performance. With the change in training constructs, the need to transform the care delivery model is now essential and a sense of urgency exists to create a model that produces quality outcomes

in an efficient and service driven organization. The advanced practice nurse may provide an element of system stabilization for the academic medical center. However, the need for post graduate fellowship, especially in the skills and knowledge necessary to function in the critical care environment, is an expressed need given the increasing complexity and acuity levels of the inpatients. A Medicare demonstration project could certainly assist and validate exploration of this potential enhancement of the advanced practitioner skill set, providing a potential solution to augment the clinical care of patients. With further regulations in resident work hours on the horizon, the need to address potential gaps in care becomes even more pressing and urgent. A viable solution has been identified and further exploration is warranted to provide a care model that produces the outcomes expected and deserved by the patients seeking care in the U.S. health care delivery system.

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Recognition of Clinical Deterioration - A Literature Review

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Abstract

Background: Recognition of clinical deterioration can be termed a "critical success factor" in every care delivery model. A systematic review of the literature related to recognition of clinical deterioration could lead to focus areas for further research in order to dissect and improve the essential skill of recognition of the "physiologic abnormalities of disease" and bring to bear, in a more timely fashion, the necessary interventions to blunt deterioration and, ultimately, improve clinical outcomes.

Methods: The CINAHL EBSCO and PubMed databases were searched for topics related to clinical deterioration. In order to be exhaustive, several key words were used to expose the maximum amount of potentially relevant literature. Results were limited to those presented in the English language. An initial review revealed citations in the articles leading to further review of related articles for potential inclusion.

Conclusions: The inpatient care unit in 2010 is overflowing with complex, acutely ill patients with the potential at any time for physiological instability. When destabilization occurs, and clinical deterioration becomes evident, the system responsiveness must be fail safe. In order to create a system of precise, non- subjective triggering of rescue systems, attention must be given to process development that automates the triggering. The review of the literature clearly demonstrates knowledge of the deterioration is not the primary issue. The actionable data is present. However, the translation, interpretation and willingness to appropriately execute by the front line provider presents a potential barrier to a precision system. Further investigation of behavioral issues as well as the potential to leverage technology could assist in breaking the "clinical futile cycle" of care and expedite the necessary resources to the patient.

Key Words: deterioration, rapid response teams, medical emergency teams, resuscitation, resuscitation of deterioration, recognition of deterioration.

Recognition of Clinical Deterioration

Over 100 years ago, Sir William Osler noted, "If you listen carefully to the patient they will tell you the diagnosis" and "Patients do not die of their disease, they die of the physiologic abnormalities of their disease" (Bean, R.B., 1950). Even in the earlier years of clinical practice, the need to assimilate key messages signaling the care provider to take action was a clear and basic tenet of quality patient care. Patient safety has increasingly become an area of focus over the preceding decade. The evolution of inpatient care has also become increasingly complex, chaotic and predicated on knowledge and mastery of multiple system signals in order to provide the highest quality care possible.

Recognition of clinical deterioration can be termed a critical success factor in every care delivery model. As critical care resources become more constrained and allocated to the most critical of patients, many patients are being shifted to less monitored venues or venues where no continuous physiologic monitoring occurs at all, except by application of clinical gestalt by the care providers based on data retrieved manually at one, two or even four-hour intervals. A systematic review of the literature related to recognition of clinical deterioration could lead to focus areas for further research in order to dissect and improve the essential skill of recognition of the "physiologic abnormalities of disease" and bring to bear, in a more timely fashion, the necessary interventions to blunt deterioration and, ultimately, improve clinical outcomes. The analysis of this literature is organized by application of a conceptual model using basic constructs of the intelligent complex adaptive system (ICAS) (Bennett and Bennett, 2004). While the application of this model is usually considered relative to organizational performance, key model applications can be used to organize thinking around the concept of clinical deterioration and the clinician's aptitude and skill to deploy interventions. The model can also be used to describe the barriers and obstacles that may exist resulting in protraction of the time to mobilize resources, clinical experts or interventions to interrupt the cycle of deterioration.

Methods

This literature review is based on a systematic approach including identification of studies included in the review, the appraisal of each study using a strength of evidence scale and documentation of key findings which would be of interest to the reader reviewing the topic of recognition of clinical deterioration. The CINAHL EBSCO and PubMed databases were searched for topics related to clinical deterioration published between 1985 and 2010. Several key words were used to expose the maximum amount of potentially relevant literature. Key words and concepts used included: deterioration, rapid response teams, medical emergency teams, resuscitation, and combinations of key concepts and words including response to deterioration, resuscitation of deterioration and recognition of deterioration. Results were limited to those presented in the English language. An initial review revealed citations in the articles leading to further review of related articles for potential inclusion.

An evidence summary table was created mapping samples, methods, findings and grades of evidence. The grading or strength of evidence was ranked according to specific criteria developed by Stetler and colleagues (1998). The criteria are particularly useful as they include greater specificity for ranking quality of literature including opinion of respected authorities and more general literature. Table 1 illustrates the definition of each level within this grading system.

Table 1

Level & Quality of Evidence	Source of Evidence
Level I	Meta-analysis of multiple controlled studies
Level II	Individual experimental study(includes studies on targeted population/issue and studies with other relevant populations/ issues)
Level III	Quasi-experimental study such as nonrandomized, controlled, single group pre-and post-test, time series, or matched case-controlled studies(includes studies on targeted population/issue and studies with other relevant populations/issues)
Level IV	Non-experimental study such as correlational, descriptive, research, and qualitative, or case studies (includes studies on targeted population/ issue and studies with other relevant populations/issues)
Level V	Case report or systematically obtained, verifiable quality, or program-evaluation data
Level VI	Opinion of respected authorities (e.g. nationally known) based on their clinical experience or the opinions of an expert committee, including the interpretation of non-research based information. This level also included regulatory and legal opinions.

Buist (2008) defined “clinical futile cycles” of care that occur when a lot of clinical activity is directed at the patient, but little of this activity relieves the dire circumstances of the patient. These protracted cycles of care are a result of clinical culture, under appreciation of patient physiologic signaling and, perhaps, increasingly

chaotic and frenetic pace experienced by front line care givers, usually registered nurses. In addition, in teaching hospitals, the changing complexion of medical resident training has resulted in a reduction of resident availability (especially senior level residents) to discuss and deploy the necessary interventions to blunt deterioration. In nonteaching hospitals, the availability of resources such as hospitalists, nocturnists, and especially, intensivists has become increasingly challenging, as has creation of a care delivery model which can adapt and respond to an increasingly complex, more acute patient population.

The changing clinical environment can be considered in the context of the intelligent complex adaptive system. Bennett and Bennett (2004) have taken the basic complex adaptive system model and added dimensions to increase relevance to the care environment of today. Bennett and Bennett noted that as we move from the manufacturing, to the information, to the complexity age, the most valuable resource becomes knowledge. Knowledge is defined as the capacity (both potential and actual) to take effective action in varied and uncertain situations. The continuous ability to take effective action is achieved through judgment, experience, context, insight, the right information and application of analysis and logic. Effective action creates value for the system or organization. In the case of recognition of clinical deterioration, the knowledge necessary to take effective action requires first isolation of the clinical signals generated by the patient and then placing those in context of the clinical experience. Clearly, the pace and hypervolemia of information could easily overwhelm even an experienced care provider. However, clear understanding of the basic rubric of clinical deterioration, developing a high index of suspicion for deterioration based on knowledge, then activating the necessary system support can go a long way in interrupting the "clinical futile cycle." Knowledge support systems can be studied, developed and deployed to assist the front line care giver in making these key assessments, timely decisions, and brisk allocation of resources to preserve the environment of safety expected and demanded by today's patients. Two key processes exist related to recognition of deterioration: the afferent conduction of data assimilation and the activation of necessary resources. First and foremost, the recognition of clinical deterioration must occur, and subsequently a brisk and timely reaction to the patient signaling deterioration must be activated by the clinician.

Recognition of Deterioration

The literature is replete with data regarding delays in deterioration recognition. These findings are present in literature related to cardiopulmonary arrest antecedents, genesis and deployment of rapid response teams (RRT) or medical evaluation teams (MET) and a newly found interest in technology to support the interpretation of deterioration and timelier alerting of clinicians. One of the key constructs of the ICAS model is the acknowledgement of the critical infrastructure needed for knowledge support systems connecting data, information and people. A summary of the literature is found in the annotated bibliography in Appendix B. Key findings from each manuscript are noted in brief as well as delineation as descriptive or interventional studies.

Hillman and colleagues (2001) identified that half of hospital deaths in their sample had physiologic abnormalities documented within eight hours of death and the same percentage had abnormalities in the period between eight and forty eight hours. Almost one third of patients had the same serious abnormalities for the whole forty-eight hour period before death. Over 60 percent of patients had identifiable deterioration of vital signs prior to death. A similar finding was noted by Franklin and Mathew (1994) in that 66 percent of patients had documented clinical deterioration within six hours of the cardiopulmonary arrest. Unplanned intensive care unit admission has also been studied regarding the preemptive period leading up to the admission (Goldhill et al., 1999). A significant worsening of the respiratory rate was noted in the 24 hours leading to intensive care unit admission. The authors also noted medical and nursing staff were aware of the patient deterioration, but did not provide the appropriate treatment. A seminal article by Schein, Hazday, Pena, Ruben and Sprung (1990) demonstrated 84 percent of the patients had documented observations of clinical deterioration or new complaints within eight hours of arrest. Seventy percent of patients had either deterioration of respiratory or mental function during the study period. Again, the absence of relevant information was not the problem, but the response to the information remained an area of concern. Consistent findings were presented by Smith and Wood (1998) in that 51 percent of patients with in-hospital cardiopulmonary arrest had premonitory signs. Similarly, another study analyzing pre-cardiac arrest diaries of events

noted 76 percent of critical event patients had instability documented for more than one hour before the event with the median duration of 6.5 hours (Buist et al., 1999).

Sax and Charlson (1987) studied medical patients at high risk for catastrophic deterioration and noted the traditional utilization of the intensive care unit for observation was compressed for critically ill patients. Thus, patients requiring intensive observation were pushed to the general wards where the tools, skills and knowledge may not have been in place for early recognition of deterioration. Clear data exists that patients who experience arrest on the floor are much less likely to survive to discharge than those who experience arrest in the critical care unit (Goldhill & Sumner, 1998; Goldhill et al., 1999; Sandroni, Nolan, Cavallaro, & Antonelli, 2007). The recognition of deterioration is clearly of issue. However, it appears in many cases the nursing and medical providers had knowledge of the signals sent by the patient who was experiencing a deterioration cycle. As Downey et al., (2008) noted, the afferent arm of the MET system might be the one in need of research and attention.

A recent clinical paper from *Resuscitation* (DeVita et al., 2010) describes the results of discussion and analysis by international experts specific to the afferent limb of a rapid response system. The afferent limb was described as the limb used to detect patients at risk and obtain help. Major findings from the consensus discussion included: (1) vital signs aberrations predict risk; (2) monitoring patients more effectively may improve outcome, although some risk is random; (3) the workload implications of monitoring on the clinical workforce have not been explored, but are amenable to study; and (4) the characteristics of an ideal monitoring system are identifiable and it is possible to characterize monitoring modalities. The afferent limb of rapid response systems is essential to further provide a more mature, sophisticated care delivery model sensitive to the complex characteristics of the acutely ill patient and activation of the necessary system of rescue. Monitoring, specifically the documentation and triggering based on obtaining specific vital signs was also explored in a recent prospective controlled trial by Mitchell et al., (2010). A multi-faceted intervention was introduced using a newly designed ward observation chart, a track and trigger system and an education program for staff. Significant reductions were seen in unplanned ICU admissions and unexpected

hospital deaths. Rapid response system activation also increased and the daily frequency of documentation of vital signs improved during the intervention period.

Resource Deployment to Blunt Clinical Deterioration

The Medical Emergency Team (MET) or the Rapid Response Team (RRT) is a concept that has been implemented as a system solution to address deterioration for more than a decade. Much of the literature related to recognition of clinical deterioration is contained within the solution studies around activation of the MET, RRT, or critical care outreach team. Only two intervention studies were found related to impact of MET. The MERIT study conducted in Australia randomized twenty three hospitals with the intervention of introduction of MET. The results demonstrated MET calls greatly increased, but there was no significant impact on incidence of cardiac arrest, unplanned ICU admission, or unexpected death. Relative to recognition of clinical deterioration, the authors noted in the unplanned ICU admission group, 50 percent had documented calling criteria more than fifteen minutes before the event, but only 30 percent of the patients had an emergency team called (K. Hillman et al., 2005). The second intervention study randomized intervention at the ward level within one hospital (Priestley et al., 2004). The study demonstrated a statistically significant reduction of in hospital mortality in the wards where the MET service was operating and demonstrated equivocal findings regarding hospital length of stay. A more recent systematic review and meta-analysis regarding rapid response teams demonstrated collectively implementation of RRT for adults was associated with a 33.8 percent reduction in rates of non ICU treated arrest. The pooled estimate regarding mortality trended toward the null and was not associated with lower mortality rates (Chan, Jain, Nallmothu, Berg, & Sasson, 2010). Several other systematic reviews (McGaughey et al., 2007; Ranji, Auerbach, Hurd, O'Rourke, & Shojania, 2007; Schmid, Hoffman, Happ, Wolf, & DeVita, 2007) suggested no consistent improvement in clinical outcomes and some studies were noted to have been of poor methodological quality.

The previous discussion demonstrates a clear, pervasive construct that is of great concern. As noted in one study, the barrier existed of “underestimation of the clinical significance of physiological perturbations” (Jones et al., 2006). The following is a

discussion of the potential clues provided in the literature regarding barriers and obstacles to prompt recognition that often leads to delayed or negligent action, even though physiologic disturbance is clear.

Potential Barriers

Several studies illustrate similar findings related to potential barriers in prompt reporting of clinical deterioration. As early as the 1990s consistent themes emerged regarding reasons for failure of nurses to initiate crisis response. Two consistent themes were the crisis was not perceived as severe enough to warrant response and the concern regarding potential reprimand if the nurse bypassed physician notification (Daffurn, Lee, Hillman, Bishop, & Bauman, 1994; Jones et al., 2006). The relationship between nurse and physician may be complicated further in a teaching environment where there often exists a layer (or multiple layers) of resident learners with a policy of escalation depending on specific situations and perceived severity of deterioration. A more systematic approach defined causes of suboptimal care as failure of organization, lack of knowledge, failure to appreciate clinical urgency, lack of supervision and failure to seek advice (McQuillan et al., 1998). One interesting characteristic that could contribute to suboptimal care was the concept of physicians and/or nurses experiencing information overload and thereby experiencing erosion in setting appropriate priorities and action items. A team noted a similar definition of inadequate response (Bedell, Deitz, Leeman, & Delbanco, 1991; Schein, Hazday, Pena, Ruben, & Sprung, 1990; Smith & Wood, 1998). The team also noted the absence of pertinent information was not the problem, but the response to the information (including inadequate or delayed communication of information to physicians, perception by physician's information is unimportant or unreliable, insufficient intervention and failure of maximal/appropriate therapy). Even with firm MET guidelines in place, the timely call for assistance given clinical deterioration remains problematic. Downey and colleagues (2008) noted the afferent arm of the MET continued to fail due to time spent in attempts by ward staff to deal with the situation, time spent by ward nursing staff seeking medical review before calling MET, limited compliance with MET criteria and limited appreciation of the need to act immediately. Although the MET or RRT intuitively makes sense to provide a systemic

response to deterioration episodes, the activation of the team remains problematic, even in a mature/sophisticated system with evolved MET guidelines for activation.

The basic tenets of the ICAS model suggest more knowledge support systems that connect data, information and people are essential to the evolution of the system. Several efforts are now underway to leverage the electronic medical record by automating collection and reporting of physiologic data and system signaling in order to further automate the "call out" for response to a deterioration episode.

Optimizing System Responsiveness to Deterioration Episodes

Automation could dispel many of the barriers noted above which are subject to individual interpretation and decision making regarding assessment of importance and urgency of need to act. Several, recent studies demonstrate real potential in single channel and, more importantly, integrated monitoring systems which can analyze conduction patterns of physiologic disturbance and report potential deterioration episodes to the appropriate individuals or team which can take immediate action (Hravnak et al., 2008; Kho et al., 2007; Tarassenko, Hann, & Young, 2006). A systematic review of the literature was conducted in 2008 to describe aggregate weighted "track and trigger" systems. The systems describe use cultivated information from patient vital signs, which feed a set of decision rules and evaluate the ability of the system to discriminate between survivors and non-survivors using area under receiver operating characteristics (AUROC) curve (Smith, Prytherch, Schmidt, & Featherstone, 2008; Smith, Prytherch, Schmidt, Featherstone, & Higgins, 2008; Smith et al., 2006). Thirty-three unique average weighted "track and trigger" systems were identified with AUROC ranging from 0.657-0.782. Twelve of the systems discriminated reasonably well between survivors and non-survivors. The top four incorporated age as a component and the top two also incorporated temperature.

Provider characteristics must also be critically appraised to optimize the care delivery model in such a way to enhance the ability to detect clinical deterioration and act promptly. More recent attention has been given to configuration of nurse delivery models including staffing models, educational levels and contextual factors of the environment regarding teaching versus nonteaching facilities (Schmid et al., 2007). A

systematic approach is needed to define the care delivery model, and optimize that model based on individual needs of patients and the context of the health care delivery system. The interaction between patient, patient acuity, front line staff, knowledge networks, and system responsiveness to crises will be an area of intense study as the need to understand the ICAS model and its potential application to health care evolves.

Conclusion

As previously noted, Sir William Osler said, “Patients do not die of their disease; they die of the physiologic abnormalities of their disease” (Bean, 1950). The inpatient care unit in 2010 is overflowing with complex, acutely ill patients with the potential at any time for physiological instability. When destabilization occurs, and clinical deterioration becomes evident, the system responsiveness must be fail safe. In order to create a system of precise, non-subjective triggering of rescue systems, attention must be given to process development that automates the triggering. The review of the literature demonstrates knowledge of the deterioration is not the primary issue. The actionable data is present. However, the translation, interpretation and willingness of front-line providers to appropriately execute response presents a potential barrier to a precision system. Further investigation of behavioral issues as well as the potential to leverage technology could assist in breaking the “clinical futile cycle” of care and expedite the necessary resources to the patient.

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Utility of an Automated Early Warning System to Accelerate Recognition of Clinical Deterioration

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Utility of an Automated Early Warning System to Accelerate Recognition of Clinical Deterioration

Deterioration is defined in the Webster dictionary (2010) as "falling from a higher to lower level in quality, character or vitality". Clinical deterioration may be defined as the physiological decompensation that occurs when a patient experiences worsening of a preexisting serious condition or acute onset of a serious physiologic disturbance. The early identification, recognition and acknowledgement of clinical deterioration of patients in the acute care setting are matters of serious concern. A need exists to prospectively characterize the etiology of physiologic deterioration as well as the temporal events leading up to the occurrence of deterioration. Integration of an automated early warning system could narrow the gap between onset of clinical deterioration and recognition of the signs of deterioration by care providers.

The purpose of this paper is to report on a study that was the focus of a final project conducted in a Doctor of Nursing Practice (DNP) program. The project was designed to retrospectively explore the impact of an automated early warning system to use physiologic data from the electronic health record to automate a rapid response activation once a specific score was exceeded. Specific aims were to:

1. Describe the demographic and clinical characteristics of the patients who experience clinical deterioration in an acute care setting including age, gender, admission, diagnosis and deterioration etiology.
2. Compare the timeliness of recognition of clinical deterioration by care providers and response by the rapid response team before and after the implementation of the early warning system triggered from physiologic variables documented within the electronic health record.
3. Analyze the impact of an early warning system based on physiologic criteria on key outcome variables including rate of cardiopulmonary arrest occurring outside the ICU setting, unplanned ICU admission, ICU length of stay when admitted from an acute care setting and overall system mortality.

Literature Review

Systems of responsiveness to physiological deterioration have been debated in the literature for approximately fifteen years (Buist et al., 1999; Goldhill et al., 1999; Hillman et al., 2005; Schein et al., 1990). Also, a significant body of research exists which suggests the events of clinical deterioration leading to team activation or an acute event requiring emergency response are often preceded by documented signals of insidious deterioration. For instance, Schein et al., (1990) found that patients had documented clinical deterioration within eight hours of cardiac arrest. Later, Franklin and Mathew (1994) noted a comparable figure of 66 percent of patients had documented clinical deterioration within six hours of arrest. These findings have been supported even more recently by McGauhghey et al., (2007).

McGaughey et al., (2007) published a Cochrane review entitled: Outreach and Early Warning Systems (EWS) for the Prevention of Intensive Care Admission and Death of Critically Ill Adult Patients on General Hospital Wards. Two randomized controlled trials were included in the review. The first study was conducted at the hospital level involving 23 hospitals in Australia. The second was at a ward level involving 16 wards at a hospital in the United Kingdom. The primary findings of the Australian trial indicated there were no significant differences between control and medical emergency team (MET) hospitals. In contrast, the study conducted in the United Kingdom indicated that an outreach program reduced in-hospital mortality compared with the control group. Findings of the review suggest that one approach to the problem of clinical deterioration that is accepted by many is the creation and deployment of medical emergency teams (MET) or rapid response teams (RRT). Typically, the teams have been created and deployed to the general ward areas of inpatient settings. Furthermore, protocols are typically developed in systems that adopt MET or RRT concepts to include triggers defined to activate the team who quickly responds to the bedside in an effort to preempt the clinical deterioration thus preventing unnecessary morbidity associated with underlying pathology.

Obviously, one of the problems facing care providers is the recognition of clinical deterioration and activation of a response that will blunt the “clinical futile cycle”

described earlier by Buist (2008). Buist defined a concept "of clinical futile cycles" which occurred when a flurry of clinical activity was directed at the patient, but little of the activity relieves the dire circumstances of the patient. The literature is replete with information suggesting that the absence of pertinent/relevant information is not the problem. Rather, the response to the information is an area of grave concern (Buist et al., 1999; Goldhill et al., 1999; Schein et al., 1990; Smith & Wood, 1998).

The only large randomized prospective study of MET implementation reported to date is the MERIT study (K. Hillman et al., 2005). The MERIT study included twenty three hospitals in Australia in a randomized trial designed to evaluate functioning as usual or introduction of a MET system to address the problem of clinical deterioration. The primary outcome evaluated was a composite of cardiac arrest, unexpected death, or unplanned critical care unit admission during the 6-month period after MET activation. Analysis was by intention to treat. Although study findings indicated no significant reduction in outcome, there was evidence of the necessary physiologic cues (demonstration of MET criteria 15 minutes before cardiac arrest) to trigger a call to the MET. In a large portion of instances (30%), the team was not activated. In addition, for those patients with unplanned critical care admission and unexpected death, the incidence of failure to activate the MET was 51 percent and 50 percent respectively (Hillman et al., 2005). The MERIT findings support the need for standardizing system responsiveness to automate triggers that activate the response system and ensure that the right provider is at the bedside in the right amount of time.

Several efforts are now underway to leverage the electronic medical record by automating collection and reporting of physiologic data and system signaling in order to further automate the "call out" for response when there is a deterioration episode. This automation could dispel many of the barriers such as fear of reprimand, difficulty in clinical integration of physiologic cues, failure to appreciate clinical urgency and failure to seek advice. Several recent studies (Hravnak et al., 2008; Kho et al., 2007; Tarassenko et al., 2006) reported findings indicating real potential in single channel and, more importantly, integrated monitoring systems which could detect and analyze patterns of physiologic disturbance and report potential deterioration episodes to the appropriate individuals or team for prompt action.

Methods

A pilot project was conducted based on a quasi-experimental design to evaluate implementation of an early warning system based on physiologic criteria imbedded in the electronic health record. The project extended over an eight month period with four months preintervention data collected and four months of data post intervention, all collected retrospectively. A University Institutional Review Board approved all study procedures.

Setting: The setting for the pilot project was acute care (nonmonitored) and telemetry units in a tertiary care hospital within an academic medical center. This regional referral center is an integrated clinical delivery system that includes a 300 bed community hospital, a 489 bed tertiary care center, an 800 physician ambulatory practice system, and a full service hospital for neonatal and pediatric care. The hospital is designated as the regional Level 1 Trauma Center and performs solid organ transplantation (heart, lung, kidney, pancreas and liver).

Sample and Sampling Procedure: Medical records of all patients experiencing clinical deterioration on select units were included in the data set. Units included approximately 240 beds serving adult medical patients, surgical patients, stroke patients, as well as patients with various other diagnoses leading to inpatient hospitalization. The patients on the units range from patients with no presence of continuous physiologic monitoring to those located in progressive care units. Medical records of patients located in the intensive care unit setting were excluded from the study.

A retrospective pre intervention sample was gathered from electronic clinical records to evaluate the current state in activation of the rapid response team based solely on judgment of the care provider (usually the patient's nurse). Preintervention data was collected for a four month period on 1,136 rapid response activations. Medical records of all patients experiencing clinical deterioration were included in the data set. An electronic note entered by the rapid response team served as the marker for clinical deterioration during the preintervention timeframe. For comparison, data was collected after the activation of the early warning system for a four-month period on 1,371 rapid response activations. All patients who experienced a physiologic state resulting in trigger of the early warning system were included. Again, the early warning system was based

on a physiologic score, which activated an automatic trigger and then response from the rapid response team. The team then entered a note in the electronic medical record for each response and these notes were used as the trigger for study inclusion in the post intervention group. The rapid response team reviewed each patient's clinical course and determined the time of onset of clinical deterioration by reviewing physiologic trend data such as blood pressure, heart rate and respiratory rate.

Instruments: The information technology department was consulted and heavily integrated in the work from its inception. Appendix C is a tool that was utilized based on a published report by Kho et al., (2007). The tool utilized physiologic variables such as blood pressure, heart rate, respiratory rate and temperature. This tool also incorporates the variables of age and body mass index into the equation. The tool was selected because of its apparent ease of application in the electronic medical record and the existence of the physiological variables depicted. In addition, early work on track and trigger methodologies indicated those tools which included age and temperature had increased sensitivity (Smith, Prytherch, Schmidt, & Featherstone, 2008; Smith, Prytherch, Schmidt, Featherstone et al., 2008). The tool was integrated into electronic medical record system architecture. Once decision rules and logic were created, the early warning system was run as a shadow system for approximately four months to determine accuracy and volume of alerts. Once preliminary data were reviewed, it was determined a total score of six would be used for the "live" system. The early warning system was activated with expectations for rapid response team activity on August 1, 2010.

Data Collection and Analysis: Deidentified Medical record data were obtained and analyzed using SPSS software. Descriptive statistics were used to depict the demographic profile of the patients experiencing deterioration in both the pre and post intervention groups. Chi square was used to evaluate differences in mortality rate and rate of cardiopulmonary arrest outside the intensive care unit. ICU length of stay and timeliness to recognition of deterioration were evaluated using T-test. Data were not available to analyze unplanned ICU admission.

Results

Descriptive statistics were used to provide a profile of patients experiencing clinical deterioration to assist in predicting those patients who may be predisposed to a deterioration event. A general demographic description is provided below for each group before and after intervention.

Table 2

	Group 1 Preintervention (n = 1136)	**Group 2 Postintervention (n = 1371)**
Age	56 (Range 18-96)	59 (Range 18-102)
Gender	46% Female; 54% Male	47% Female; 53% Male
Socioeconomic Status (Payer)	46% Patient Responsibility 31% Government (Medicare/Medicaid) 16% Commercial	36% Patient Responsibility 37% Government (Medicare/Medicaid) 21% Commercial
Day of Stay	1st 48 Hours - 26% of Activations Day 1-4 - 48% of Activations Day 1-7 - 65% of Activations	1st 48 Hours - 28% of Activations Day 1-4 - 46% of Activations Day 1-7 - 62% of Activations
Prior ICU Stay **Prior OR Procedure**	16% With Prior ICU Stay 30% With Prior OR Procedure	44% With Prior ICU Stay 36% With Prior OR Procedure
Deterioration Etiology	Respiratory - 327 Neurologic - 120 Cardiac - 207 Sepsis - 669	Respiratory - 190 Neurologic - 57 Cardiac - 119 Sepsis – 363 Unable to Determine – 642

Timeliness of recognition of clinical deterioration: The T-test procedure was used to compare timeliness of recognition of deterioration for the two groups. The preintervention group relying on nurse activation of rapid response team for deterioration and the postintervention group using the automated early warning system for team activation based on physiologic and demographic cues. The t-test revealed that the time to deterioration recognition was significantly faster in the group utilizing the automated early warning system ($t=11.99$, $p<.0001$). The mean time from onset of deterioration and time of activation of rapid response team for the preintervention group was 571.2 minutes, while the mean time was 93.7 minutes for the post intervention group.

Impact of Early Warning System: Several outcome variables were evaluated to gauge impact of activation of the early warning system. Mortality rate for the two groups was compared. The difference in mortality rates was not statistically significant at the .05 level (preintervention 14.6% and post intervention 16.6%). Instance of cardiopulmonary arrest occurring outside the intensive care unit was also evaluated between the two groups. A statistically significant result was found ($p<0.05$) when comparing the rate of cardiopulmonary arrest between the two groups. The rate of arrest in the preintervention group was 5.54 percent and in the post intervention group 3.86 percent ($p=0.046$).

Intensive Care Unit Length of Stay and Unplanned ICU Admission: The ICU length of stay was evaluated between the two groups. The mean ICU length of stay for the preintervention group was longer (3.8 days) than the postintervention group (3.3 days). There was not a statistically significant difference in total ICU length of stay between the two groups ($t=1.74$, $p=.08$). However, the clinical significance of the reduction of 0.5 day in the critical care environment should be carefully considered. The ICU length of stay reduction could impact throughput and more effective management of expensive ICU resources. Data were not available to measure unplanned ICU admission.

Discussion

Patients hospitalized on acute care wards who suffer clinical deterioration are most safely managed when recognition and treatment occur quickly. Effective care delivery models provide for rapid and reliable response to episodes of physiologic deterioration. It is not currently economically practical or clinically appropriate to continuously monitor all patients on acute care wards. Therefore, effective care delivery models must trigger just-in-time experts who possess the sophisticated clinical skills essential for rapid recognition and intervention when physiologic deterioration manifests. Clinical expertise is gained from education and training as well as work experience. In the aviation industry, studies have shown that experienced pilots can more quickly and effectively respond to crises compared to less experienced colleagues. Similarly, in the field of nursing, education and training have been shown to be associated with better outcomes (Aiken, Clarke, Silber, & Sloane, 2003). Aiken et al. (2003) demonstrated that a 10 percent increase in proportion of workforce nurses holding a bachelor's degree was associated with a 5 percent decrease in both likelihood of patients dying within 30 days of admission and the odds of failure to rescue. Aiken however called into question the conventional wisdom that experience levels alone lead to higher performance and suggested that this concept be questioned and further studied. Unfortunately, delayed recognition of episodes of clinical deterioration and efficient initiation of interventions continue to plague otherwise effective care delivery models.

In this study, the investigators tested an automated early warning system designed to more quickly and reliably assist nurses in identifying the sometimes subtle signs of clinical deterioration. The current model of care relied upon the bedside nurse and nursing assistants to continuously evaluate patients and enter vital sign data into the electronic medical record in a timely fashion and constantly assess whether rapid intervention was needed. With the automated early warning systems, pre-determined physiologic criteria were met and then the rapid response team was automatically paged to the patient's room. In the investigators institution, the rapid response team is composed of well educated and experienced critical care nurses. The rapid response nurses would then make the clinical decision of whether or not care escalation was necessary and initiate those interventions as needed.

In this study, application of the automated activation tool increased the number of rapid response notifications by approximately 30 percent. This increase in activations can be attributed to the rigid and reliable mathematical nature of the early warning system. Prior to the implementation of the early warning system, 1,136 rapid response interventions were called, compared to 1,371 rapid response interventions post-implementation. The demographics of the patients who were evaluated in the pre and post-implementation groups were not statistically different when considering age, gender, socioeconomic status or day of hospital stay when deterioration occurred. The average age of all patients was 58. Approximately 60 percent of the deteriorations occurred within the first seven days of admission to the hospital, and 45 percent occurred within the first 4 days of the hospital stay. Interestingly, a difference was found between the two groups regarding an ICU stay prior to the deterioration event, but this difference did not reach statistical significance. In the pre-intervention group, only 16 percent of patients had a prior ICU stay compared to the post-implementation group where 44 percent of the patients had previously been in the ICU during the hospitalization.

The etiology of deterioration was captured by the rapid response team and provided some interesting findings. When recording etiology, more than one category was available for selection. The pre-intervention group relied solely on provider activation of the rapid response team for a deterioration episode. The overt signs of deterioration including respiratory insufficiency and/or suspected sepsis were the primary drivers of team activation in the pre-intervention group. Often, these physiologic endpoints become overt visible signs of deterioration, when the actual clinical onset of the event had begun approximately nine hours earlier. The post-intervention group demonstrated fewer activations based on the system categories provided, which suggests that team activation was more likely the result of several variables including age, BMI, temperature and earlier, more subtle physiologic derangements. Use of the automated early warning system was associated with a significant reduction in the "onset-to-recognition time" for deterioration from 9 hours, in the pre-intervention group, to 1.5 hours in the post-implementation group. This difference was statistically significant at the $p<.0001$ level. This finding provides strong evidence that the activation of an automated

early warning system improved care model responsiveness to physiologic deterioration and helped preempt treatment delays due to futile cycles of care.

Rapid treatment for patients suffering physiologic deterioration should decrease the likelihood that full cardiac arrest will ensue. In this study there was a significant decrease in cardiac arrest rates for the post-implementation group. The cardiac arrest rate in the pre-implementation group was 5.55 percent compared to only 3.87 percent in the post-implementation group. This difference was significant with a chi square value of 3.97 significant at the $p = 0.0462$ level. Timely activation of the response team with focused attention to clinical deterioration earlier in the evolution of the pathophysiologic process may be responsible for preventing progression of the deterioration episode to an arrest situation. This finding could have a significant impact on the design and implementation of similar automated systems of response. Relying on a purely subjective interpretation of the deterioration episode could lead to unnecessary delays in team activation or deferred activation to avoid retaliation from other providers on the team. By automating system responsiveness, the emotion and potential consideration of consequences related to team dynamics are removed from the equation and the system can provide peak performance in response to deterioration episodes. The scoring system will require ongoing evaluation and refinement of activation criteria to avoid over-activation and alert fatigue. This deleterious effect of early warning systems that can lead to system tiring due to overutilization of the team, has been clearly documented in recent literature (ECRI, 2010). As noted earlier, the demographic profile does not provide clear insight regarding population differences in those patients experiencing clinical deterioration. Subsequent analysis could prove to identify variables that may be essential to predicting a deterioration event. Kho, et al. (2007) provided a beginning tool to apply in order to detect the onset of clinical deterioration through physiologic and demographic variables. Univariate analysis could prove beneficial in identifying the most important variables assigning those variables a higher weight in an effort to increase the specificity of the scoring system while still maintaining an acceptable sensitivity. In addition, the structure of the care model should also be carefully scrutinized to ensure a brisk, expert response once detection has occurred.

Conclusion

Documentation of the significant improvement in detection of the onset of clinical deterioration using an electronic early warning system is a critical finding. The acceleration of detection from 571 minutes (9.5 hours) to 94 minutes (1.5 hours) is substantive and provides a compelling incentive to consider similar application in other care models. Given the fact many facilities are on the journey toward electronic medical records, leveraging the data in the record to achieve improved quality outcomes is essential. The incidence of cardiopulmonary arrest occurring outside the ICU also is a clear marker for the improved care model performance, especially when caring for critically ill, high intensity patients who are now found on inpatient units with no continuous physiologic monitoring. Creating a highly reliable, reproducible care model that leverages data found in the electronic medical record can provide substantive improvements to system performance, and, ultimately patient outcomes.

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Tarassenko, L., Hann, A., & Young, D. (2006). Integrated monitoring and analysis for early warning of patient deterioration. *Br J Anaesth, 97*(1), 64-68.

Capstone Report Conclusion

Detection of clinical deterioration is an essential infrastructure priority for the care delivery model of the future. Today's acute care unit in a hospital setting is overflowing with complex, high acuity patients with a tremendous risk of deterioration. Designing the care model structure, implementing a high reliability process of care and ensuring evidence based evaluation of outcomes is a responsibility of clinical leadership. Although our care providers have evolved to become knowledge workers, the electronic medical record should be leveraged to facilitate their contribution and best thinking in caring for patients. Careful consideration should be given to the preparation and skill set of front line care providers (structure). Additionally, support systems (process) should be constructed in a manner to provide support for the providers in critical thinking and management of decision-making. Continuous improvement (outcome) of our care models must be deliberately and carefully managed to ensure optimization of clinical outcomes.

The implications of the presented work for practice, education and research should be carefully considered. The practice implications include those of the integration of the advanced practice registered nurse into the care model, especially in academic medical centers. Education of front line providers and those with administrative oversight for operations must include awareness regarding the clinical phenomena of deterioration. Future research implications should prioritize ongoing refinement of tools, skill sets and competencies to further pre-empt or detect deterioration episodes.

Although our systems are replete with data, managing the data in such a way to inform leadership of critical junctures where outcomes may be optimized is essential. Laser focus on quality outcomes is an imperative for all of clinical leadership. Detection of deterioration is an area where providers and systems can contribute and improve patient experience and ultimate clinical end points. Deterioration could be viewed as the next hospital acquired condition, which should be studied, managed, and ultimately, eliminated through expert, high reliability systems of care.

Appendix A

Medicare Demonstration Project:
Using Acute Nurse Practitioners to Accelerate the Quality/Safety Value Proposition

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Current State: The United States is undergoing a transformation in the health care delivery system. The transformation is a result of health care reform, changes in traditional models of care delivery, and increasingly complex and intense acuity levels of patients in the inpatient setting. The Commonwealth of Kentucky presents a set of unique characteristics. The flagship academic medical center, University of Kentucky HealthCare anchors the regional system of care delivery as the primary tertiary referral center in a rural model of care delivery. UK HealthCare is surrounded by a network of community based hospitals across a vastly underserved Appalachian region in terms of health care providers, facilities and access. The most complex and critically ill patients are routinely transferred from referral facilities to the academic medical center. Vulnerability in the care delivery model has been exposed as the culmination of a number of variables has peaked. The variables include a historic care model predicated on resident coverage, increasing complexity and acuity of patients, surges in volumes of inpatient transfers and more precise evaluation of care processes as industry and consumer expectations evolve related to high quality, low cost care. An imperative exists for rapid cycle testing of new care models to provide the expected deliverables of quality outcomes in a safe care environment at a lower cost.

Future State: The future state will demonstrate a highly evolved partnership between physician and nurse practitioner evidenced by a high performing care delivery model. The evolving model will have implications for Kentucky's two academic medical centers and community based hospitals. The vulnerability in the care delivery model defined previously exists in many inpatient facilities across the Commonwealth and is not unique to the academic medical center. Many community facilities in the Commonwealth are realizing a gap in care due to difficulties in recruitment of health care

providers, employee retention and economic viability. A regional network of facilities defining and organizing the demand for care providers to fill the gap, and then participating in residencies for the providers will serve to strengthen the regional referral network and individual provider level of expertise and skill set.

Proposal: Funding of a Medicare Demonstration Project to provide a 12-month residency post completion of an acute care nurse practitioner educational program with a focus on developing a nurse intensivist. The nurse intensivist will gain added knowledge and clinical skills in procedural competencies, critical thinking, interdisciplinary collaboration and management of complex, high acuity inpatients. The Demonstration project would fund 2-5 residents per year for 2 years with evaluation of clinical and fiscal impact one year following completion of the residency. A supply and demand model would be developed as a regional health care delivery system to ensure additional training of providers for community based hospitals to infuse not only the academic medical center, but also the referral facilities with high performing nurse intensivists. Ultimate outcomes would include higher care quality at a lower cost and can best be achieved by system integration with a rural care delivery model that includes an academic medical center and community based hospitals.

Appendix B

Annotated Bibliography

Descriptive Studies				
Citation	**Sample**	**Method**	**Findings**	**Evidence Grade**
Alfred, G., Folk, B., Crecelius and Campbell, W. (1989). Pre-arrest morbidity and other correlates of survival after in-hospital cardiopulmonary arrest. *The American Journal of Medicine, 87*, 28-34.	140 consecutive hospitalized patients experience-ing cardiopul-monary arrest and received CPR.	Devised a multifactorial scoring system, the Pre-Arrest Morbidity (PAM) Index to evaluate pre-arrest morbidity in individual patients.	77 (55%) of patients successfully resuscitated, 34 (24.3%) discharged from hospital alive and 29(20.7%) were long-term survivors (alive 3 months post discharge). Pre-arrest clinical variables with significant association with mortality were hypotension, azotemia and age 65 years or older. PAM index was a significant independent predictor of mortality	Level IV
Bedell, S., Deitz, D., Leeman, D. and Delbanco, T. (1991). Incidence and characteristics of preventable iatrogenic cardiac arrests. *JAMA, 265* (21), 2815-2820.	Reviewed all patients undergoing CPR at a 504-bed university teaching hospital.	Chart reviewed within 24 hours of arrest. Used a standardized database and retrospectively obtained information from medical record about possible associations between iatrogenic complications and cardiac arrest.	Causes of iatrogenic arrest: complications from procedures, errors in use of medication, insufficient recognition or response. 14% of cardiac arrests were iatrogenic. Medications, procedures and suboptimal attention to clinical signs and symptoms were principal causes. Two main groups of potentially preventable cardiac arrests: related to medications and those caused by physician failure to recognize or respond to patient's signs and symptoms. Comment that "therapeutic hyper-enthusiasm" partly responsible with information overload causing physicians to miss important findings.	Level IV
Bellomo, R., Goldsmith, D., Uchino, S., Buckmaster, J., Hart, G., Opdam, H., Silvester, W., Doolan, L. and Gutteridge, G. (2003). A prospective before and after trial of a medical emergency team. *Medical Journal of Australia, 179*, 283-287.	Consecutive patients admitted before (21,090) and after (20,921) team imple-mentation	Prospective before and after trial in a tertiary referral hospital to determine effect of cardiac arrests and overall hospital mortality of an intensive care based medical emergency team.	Incidence of in hospital cardiac arrests decreased by 2/3 after introduction of MET. More than 50% reduction in number of cardiac arrest related deaths and a reduced number of post-cardiac arrest bed days. 26% reduction in overall hospitality mortality.	Level III

Buist, M., Jarmolowski, E., Burton, P., Bernard, S., Waxman, B. and Anderson, J. (1999). Recognizing clinical instability in hospital patients before cardiac arrest or unplanned admission to intensive care-A pilot study in a tertiary-care hospital. *Medical Journal of Australia, 171*, 22-25.	122 critical events in 112 patients during 12 month period	Retrospective review of medical records of all patients having critical events over twelve-month period. Data on hospital and ICU patients obtained for comparison with study population	76% of critical event patients had instability documented for more than one hour before the event, with median duration of 6.5 hours (range was 0-432 hours). Primary instability factors were haemodynamic and respiratory. Principles and protocols for urgent resuscitation of patients were not extended to hospital wards. Specifically securing airway, stabilize respiratory system and restore circulation. In 30% of events, documented instability had continued for more than 24 hours.	Level IV
Buist, M., Moore, G., Bernard, S., Waxman, B., Anderson, J. and Nguyen, T. (2002). Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital; preliminary study. *BMJ, 324*, 1-5.	All patients admitted to the hospital in 1996 (n=19,317) and 1999 (n=22,847)	Non randomized population based study before and after introduction of the medical emergency team	Incidence of unexpected cardiac arrest was 3.77 per 1000 hospital admissions in 1996 and 2.05 per 1000 hospital admissions in 1999 with mortality being 77% and 55% respectively. After adjustment for case mix index, the intervention was associated with a 50% reduction in the incidence of unexpected cardiac arrest.	Level III
Buist, M., Harrison, J., Abaloz, E. and Van Dyke, S. (2007). Six years of cardiac arrests and medical emergency team alls in an Australian outer metropolitan teaching hospital. *British Medical Journal, 335*, 1210-1212.	6 years review of cardiac arrest calls (271) and MET activations (1534)	Single, 400 bed hospital, prospective audit of cardiac arrests and data on use of MET during 2000 to 2005.	Incidence of cardiac arrest reduced 24% per year from 2.4/1000 admissions in 2000 to 0.66/1000 admissions in 2005.	Level IV
Buist, M. (2008). The rapid response team paradox: Why doesn't anyone call for help? *Critical Care Medicine, 36* (2), 634-636.	Editorial		Uncover the "clinical futile cycles" which occur when a lot of clinical activity is directed at the patient, but little of this activity relieves the dire circumstances of the patient. Health information communication technology needs to demonstrate much greater innovation in developing new solutions providing real time patient information to healthcare providers, including patient alerts and alert logic for timely clinical response. Also must discover and dissolve barriers preventing staff from calling for appropriate and timely help for patients. Who should resuscitate critically ill patients, regardless of location? We must decide. All staff should be trained in management of complex critically ill ward patients.	Level VI

Chan, P., Jain, R., Nallmothu, B., Berg, R. and Sasson, C. (2010). Rapid response teams-a systematic review and meta-analysis. *Archives of Internal Medicine, 170* (1), 18-26.	Systematic Review and Meta-Analysis RRT studies total sample of 1,271,864 admissions (580,776 during control and 691,088 during interventio n). All published during or after 2000 with 9 (50%) since 2007.	Meta analysis to assess effect of RRTs on reducing cardiopulmonar y arrest and hospital mortality rates.	Adults-7 studies showed significant reduction in rates of arrest whereas 4 did not. Collectively, implementation of RRT for adults was associated with 33.8% reduction in rates of non ICU treated arrest. 5 pediatric studies, 4 reported significant reduction in rates of arrest outside ICU. Cumulative pooled estimate regarding mortality has trended toward the null and was not associated with lower mortality rates. In pediatrics, an overall 21.4% in hospital mortality reduction, not robust to sensitivity analysis. Increased triage to ICU by RRT without observable survival gains could increase hospital costs without outcome yield.	Level I
Daffurn, K. Lee, A. Hillman, K.M. (1994). Do nurses know when to summon emergency assistance? *Intensive Critical Care Nurse, 10*, 115-120.	Question-naire distributed to 141 nurses, 130 returned completed (92%). Majority (62%) general medical/ surgical wards.	Distribution of a two-page questionnaire to all nursing staff on duty at afternoon shift changeover on chosen study date. Question-naire completed and returned within 30 mins. Asked to list 3 conditions for MET and 4 hypothetical situations and if MET should be called.	Two potential reasons for failure of nurses to initiate crises response: (1.) Crisis not severe enough to warrant MET response (when presented with hypothetical patient scenarios, nurses called MET only 2.8% of the time it was indicated) (2.) Nurses concerned may be reprimanded if bypassed the resident if severity of illness did not warrant MET response. Both barriers existed although nurses had favorable attitude toward MET response	Level V
DeVita, M.A., Braithwaite, R.S., Mahidhara, R., Stuart, S., Foraida, M. and Simmons, R.L. (2004). Use of medical emergency team responses to reduce hospital cardio-pulmonary arrests. *Quality and Safety in Health Care, 13*, 251-254.	3,269 MET responses and 1220 cardiopul-monary arrests over 6.8 years	Retrospective analysis of MET response rate after institution of objective activation criteria	Increase in MET response from 13.7 to 25.8 per 1000 admissions ($p<0.0001$) after instituting objective activation criteria. Coincident 17% decrease in incidence of cardiopulmonary arrests from 6.5 to 5.4 per 1000 admissions ($p=0.016$). Proportion of fatal arrests was similar before and after increase in use of MET	Level IV

DeVita, M., Smith, G., Adam, S., Adams-Pizarro, I., Buist, M., Bellomo, R., Bonello, R., Cerchiaria, E., Farlow, B., Goldsmith, D., Haskell, H., Hillman, K., Howell, M., Hravnak, M., Hunt, E., Hvarfner, A., Kellett, J., Lighthall, G., Lippert, A., Lippert, F., Mahroof, R., Myers, J., Rosen, M., Reynolds, S., Rotondi, A., Rubulotta, F. and Winters, B. (2010). Identifying the hospitalized patient in crisis-A consensus conference on the afferent limb of Rapid Response Systems, *Resuscitation, 81,* 375-382.	Consensus conference of inter-national experts in safety, rapid response systems, healthcare technology, education and risk prediction convened to review current knowledge and opinion on clinical monitoring.	Used established consensus procedures to evaluate four topic areas: (1.) To what extent do physiologic abnormalities predict risk for patient deterioration? (2.) Do workload changes and their potential stresses on the healthcare environment increase patient risk in a predictable manner? (3.) What are the characteristics of an "ideal" monitoring system, and to what extent does currently available technology meet this need? (4.) How can monitoring be categorized to facilitate comparing systems?	Vital signs aberrations predict risk. Monitoring patients more effectively may improve outcome, although risk is random. Workload implications of monitoring on the clinical workforce have not been explored but are amenable to study and should be investigated. Characteristics of an ideal monitoring system are identifiable, and it is possible to categorize monitoring modalities. May also be possible to describe monitoring levels, and a system is proposed.	Level VI
Downey, A., Quach, J., Haase, M., Haase-Fielitz, A., Jones, D. and Bellomo, R. (2008). Characteristics and outcomes of patients receiving a medical emergency team review for acute change in conscious state or arrhythmias. *Critical Care Medicine, 36* (2), 477-481.	2 cohorts of 100 patients from university teaching hospital	Retrospective analysis of medical records for each of the MET syndromes of acute change in conscious state or arrhythmia.	Delayed MET activation more common in patients with change in conscious state. Approximately 30% of patients had delay between presence of documented MET call criteria and the actual call being made with a mean delay of > 13 hours. Confirm the afferent arm of the MET system may be one in most need of research and attention. Reasons: time spent in attempts by ward staff to deal with situation, time spent by ward nursing staff seeking medical review before calling MET, limited compliance with MET criteria, limited appreciation of need to act immediately.	Level IV

Franklin, C. and Mathew, J. (1994). Developing strategies to prevent in-hospital cardiac arrest: Analyzing responses of physicians and nurses in the hours before the event. *Critical Care Medicine, 22* (2), 244-247.	21,505 total admissions to medical service over 20-month period. Excluded patients whose cardiac arrests occurred in Emergency department and ICU and patients with do not resuscitate orders	150 cardiac arrests (cardiac arrest rate of 7.0/1,000 patients) Chart review within 48 hours via protocol with 3 goals: was patient discharged from ICU during same hospitalization, was cardiac arrest preceded by clinical signs or symptoms and was notification and treatment appropriate before arrest.	66% of patients had documented clinical deterioration within 6 hours of arrest. Problem is commonly not absence of pertinent information, but clinical response to information. 3 major findings related to clinical personnel: nurse who initially examined patient often failed to notify the physician when nurse documented a clinical deterioration. Physician first aware of patient status tended to ignore arterial blood gas analysis in evaluating signs and symptoms of pulmonary insufficiency or central nervous system compromise. Physician responsible for transfer to ICU underestimated need to stabilize patient (intubation or vasopressor) before transfer. Patients discharged from ICU had arrest rate more than twice that of all other patients	Level IV
Goldhill, D. and Sumner, A. (1998). Outcome of intensive care patients in a group of British intensive care units. *Critical Care Medicine, 26* (8), 1337-1345.	12,762 admissions from 15 ICUs	Retrospective review of cases to assist in identification of priorities for intensive care unit intervention and research.	Patients admitted from wards had a much higher percentage mortality rate (52.9%) than patients admitted from either operating room/recovery (22.3%) or the accident and emergency room (30.2%)	Level IV
Goldhill, D., White, S. and Sumner, A. (1999). Physiological values and procedures in the 24 h before ICU admission from the ward. *Anaesthesia, 54,* 529-534.	Over 13 month period, 79 admission on 76 patients who had been in hospital for at least 24 hours and had not undergone surgery within 24 hours of admission to intensive care	Collection of physiological values and interventions in the 24h before entry to intensive care from hospital ward.	923 admissions to ICU 168 were from wards. Heart rate and respiratory rate were most abnormal of physiologic parameters. There was a significant worsening of the respiratory rate over the 24 hours before ICU admission, which did not occur with heart rate. Respiratory rate, heart rate and adequacy of oxygenation are most important physiologic indicators of critically ill ward patient. Medical and nursing staff are probably aware of most critically ill patients but, in many cases, do not provide the appropriate treatment.	Level IV

Hillman, K., Bristow, P., Chey, T., Daffurn, K., Jacques, T., Norman, S., Bishop, G.F. and Simmons, G. (2001). Antecedents to hospital deaths. *Internal Medicine Journal, 31*, 343-348.	Total of 50,942 inpatients treated over 6 month period, with sample of 778 deaths	Study conducted at 3 separate acute care hospitals. Demographics of all deaths recorded over 6-month period as well as antecedent factors within 0-8 and 8-48 hours of all deaths including vital sign abnormalities, cardiorespira-tory arrests and admission to intensive care. "Not for resuscitation" deaths had separate analysis	Total of 778 deaths with 549 (71%) not for resuscitation. 171 (22%) preceded by arrest and 160 (21%) preceded by admission to intensive care. Of remaining deaths, 30% had severely abnormal physiological abnormalities documented. Concern about patient condition expressed in patient notes by nursing and junior medical staff in 1/3 of non-DNR deaths. Hypotension (30%) and tachypnea (17%) were most common antecedents in non-DNR deaths. Half of all deaths without DNR orders had serious physiologic abnormalities documented within 8 hours of death and same percentage had abnormalities in the period between 8 and 48 hours. Almost 1/3 had same serious abnormalities for the whole 48-hour period before death. Between 60 and 84% of patients had identifiable deterioration of vital signs. Epilepsy was only disease specific illness for defining at risk hospital patients.	Level IV
Hravnak, M., Edwards, L., Clontz, A., Valenta, C., DeVita, M. and Pinsky, M. (2008). Defining the incidence of cardiorespiratory instability in patients in step-down units using an electronic integrated monitoring system. *Archives of Internal Medicine, 168* (12), 1300-1308.	8-week period, data obtained on 326 monitored patients in step down unit. 18,248 monitoring hours captured	Descriptive, prospective, single blinded observational study. Used an IMS (integrated monitoring system) combining heart rate, blood pressure, respiratory rate and peripheral oxygen saturation into a single neural networked signal, then analyzed for triggering sensitivity regarding cardiorespira-tory instability	Continuous peripheral oxygen saturation monitoring was unit standard, yet only done 70% of the time. Most patients were stable during their entire step down unit stay. Cardiorespiratory instability that reached MET activation occurred in different patterns. In 7 patients with MET activation, the IMS trigger occurred a mean of 6.3 hours before activation of MET. Deterioration was evident in all patients before MET activation. OF all patients who met mandatory criteria for MET activation, only 17% MET activations occurred.	Level IV

Jones, D., Bladwin, I., McIntyre, T., Story, D., Mercer, I., Miglic, A., Goldsmith, D. and Bellomo, R. (2006). Nurses' attitudes to a medical emergency team service in a teaching hospital. *Quality and Safety in Health Care, 15*, 427-432.	351 ward nurses	Conducted modified personal interview immediately before hand off on ward. Used a 17-item Likert agreement scale questionnaire	Despite hospital protocol, 72% of nurses suggested they would call the covering doctor before the MET for sick ward patient. 81% indicated they would activate MET if they were unable to contact covering doctor. Despite presence of protocol, nurses use judgment and discretion and sometimes ignore the protocol for activation. A barrier was noted as the "underestimation of the clinical significance of the physiological perturbations associated with presence of MET call criteria	Level IV
Kho, A., Rotz, D., Alrahi, K., Cardenas, W., Ramsey, K., Liebovitz, D., Noskin, G. and Watts, C. (2007). Utility of commonly captured data from an HER to identify hospitalized patients at risk for clinical deterioration. AMIA 2007 Symposium Proceedings.	1,878 patients had scores recorded and analyzed	Based scoring system on previously validated MEWS, performed retrospective analysis of prior RRT calls to determine common data elements triggering call to RRT. Added age and BMI. Resulting scoring system consisted of MEWS minus AVPU score plus age and BMI score.	Area under receiver operating curve for prediction model was 0.72 that compared favorably to other scoring systems. An electronic scoring system using readily captured EMR data may improve identification of patients at risk for clinical deterioration.	Level IV
McGaughey, J., Alderdice, F., Fowler, R., Kapila, A., Mayhew, A. and Moutray, M. (2009). Outreach and early warning systems (EWS) for the prevention of intensive car admission and death of critically ill adult patients on general hospital wards (Review). The Cochrane Collection, Issue 3.	Two cluster-randomized trials were included-one randomized at hospital level (23 hospitals in Australia) and one at ward level (16 wards in the UK)	3 review authors independently extracted data and 2 review authors assessed the method-ological quality of the included studies.	Primary outcome in Australian trial showed no statistical significant difference between control and MET hospitals (adjusted p value 0.640). The UK based trial found outreach reduced in hospital mortality compared with control group. The lack of evidence on outreach requires further multi site RCTs to determine potential effectiveness.	Level I

McQuillan, P., Pilkington, S., Allan, A., Taylor, B., Short, A., Morgan, G., Nielsen, M., Barrett, D. and Smith, G. (1998). Confidential inquiry into quality of care before admission to intensive care. *British Medical Journal, 316*, 1853-1858.	A cohort of 100 consecutive adult emergency admissions, 50 from large district general hospital and 50 from a teaching hospital	Prospective confidential inquiry on basis of structured interviews and questionnaires. Outcome measures were opinions of two external assessors on quality of care especially recognition, investigation, monitoring and management of abnormalities of airway, breathing, circulation, oxygen therapy and monitoring.	Suboptimal care occurred in 41-64% of patients in each APACHE decile (all levels of severity of illness). Assessors believed between 4.5% and 41% of admissions were potentially avoidable. Major causes of suboptimal care identified as failure of organization, lack of knowledge, failure to appreciate clinical urgency, lack of supervision, and failure to seek advice.	Level III

Mohammed, M., Hayton, R., Clements, G., Smith, G. and Prytherch, D. (2009). Improving accuracy and efficiency of early warning scores in acute care. *British Journal of Nursing, 18* (1), 18-24.	Full complement of nurses (n=26) based on two surgical assessment units in NHS hospitals.	To determine if provision of computer aided scoring could increase accuracy and efficiency of EWS calculations when compared with traditional pen and paper methods. 3 phases: (1.) Classroom based exercise where nurses given 10 vignettes and asked to derive EWS (2.) Same as phase 1, but using hand held computer to derive EWS (3.) Same as phase 2, but a follow up exercise undertaken in ward environment 4 weeks after computer aided scoring implemented in the two wards	Phase 1-significant overall accuracy 152/260 or 58% compared with phase 2 (96%-difference in proportions 38%, 95% CI 31-44%, p <0.0001). Small but significant reduction in accuracy from phase 2 (96%) to phase 3 (88%). 8% difference p=0.006. Mean time to derive EWS reduced from 37.9 seconds in phase 1 to 35.2 seconds in phase 2 (p=0.016) down to 24.0 seconds in phase 3 (p<0.0001). A handheld computer helps to improve accuracy and efficiency of EWS in acute hospital care and is acceptable to nurses.	Level IV
Ranji, S., Auerbach, A., Hurd, C., O'Rourke, K. and Shojania, K. (2007). Effects of rapid response systems on clinical outcomes: systematic review and meta analysis. *Journal of Hospital Medicine, 2* (6), 422-432.	13 studies included: 1 cluster-randomized RCT, 1 interrupted time series and 11 before-after studies	Searches through August 2006	Nearly all studies did not discuss aspects of hospital context such as nurse-staffing ratio, ICU bed availability, overall hospital census, or availability of intensivists or hospitalists. Published studies have not found consistent improvement in clinical outcomes and have been of poor methodological quality.	Level 1

Sandroni, C., Nolan, J., Cavallaro, F. and Antonelli, M. (2007). In hospital cardiac arrest: incidence, prognosis and possible measures to improve survival. *Intensive Care Medicine, 33*, 237-245.	Literature Review	Literature review on in-hospital cardiac arrest to summarize: incidence and survival, major prognostic factors, possible interventions to improve survival	Event variables influencing outcome are first monitored rhythm, event intervals and event location. IHCA outcome better if first rhythm is ventricular fibrillation/pulseless ventricular tachycardia rather than non VF/VT. Survival higher when CPR started within one minute after collapse. Shorter duration of arrest patients have better outcomes. Majority of studies report better outcomes occurring in critical care versus ward. Explanations include: monitored and witnessed status of all arrests, immediate availability of ALS, younger age and better selection of patients to be resuscitated through effective use of DNR policies.	Level IV
Sax, F. and Charlson, M. (1987). Medical patients at high risk for catastrophic deterioration. Critical Care Medicine, 15 (5), 510-515.	All patients admitted to medical service during one month (n=603) 544 were included	Patients evaluated prospectively for severity of illness and stability by the admitting residents, course of patients reviewed blindly by observers. Objective to develop criteria to demarcate patients at risk for catastrophic deterioration	Patients admitted with acute dyspnea, particularly those with chronic pulmonary disease were at a significantly greater risk of arrest ($p<.01$). Noted patients admitted to ICU for observation is compressed by more critically ill patients and patients needing close observation. Arrest occurred in setting of deterioration of a pre-existing condition…the only other significant predictor of arrest was acute dyspnea. Data supportive of other data in literature that survival to discharge after resuscitation for arrest is better in patients who are in critical care units than those on floor.	Level IV
Schein, R., Hazday, N., Pena, M., Ruben, B. and Sprung, C. (1990). Clinical antecedents to in-hospital cardiopulmonary arrest. *Chest, 98*, 1388-1392.	4 month period at 1,200 bed university affiliated hospital-64 patients identified	Studied a group of consecutive general hospital ward patients developing cardiopulmon-ary arrest.	84% had documented observations of clinical deterioration or new complaints within 8 hours of arrest. 70% of all patients had either deterioration of respiratory or mental function observed during this time. The absence of pertinent information was not the problem, but the response to the information. Inadequate or delayed communication of information to physicians, perception by physician staff such information unimportant or unreliable, insufficient intervention, failure of maximal/appropriate therapy.	Level IV

Schmid, A., Hoffman, L., Happ, M.B., Wolf, G. and DeVita, M. (2007). Failure to rescue-a literature review. *The Journal of Nursing Administration, 37* (4), 188-198.	Literature Review	Search conducted through OVID and MEDLINE from 1965 to April 2005. Articles examined were research studies that explored the influence of hospital characteristics and registered nurse staffing on failure to rescue events and effectiveness of RRT.	Failure to rescue defined as a death occurring after patient develops complication in the hospital not present on admission. Increased risk of failure to rescue with presence of surgical house staff ($p<.05$)-Silber, et al. High values of registered nurse staffing were associated with hospitals in model that had a low risk of failure to rescue. Aiken-1 additional patient per nurse associated with 7% increase in likelihood of dying within 30 days of admission and a 7% increase in odds of failure to rescue. (Nurses in best position to initiate action that could minimize negative outcomes and prevent failure to rescue events). Also-10% increase in proportion of nurses with BSN associated with decrease in failure to rescue by 5%.	Level IV
Smith, A. and Wood, J. (1998). Can some in-hospital cardio-respiratory arrests be prevented? A prospective survey. *Resuscitation, 37*, 133-137.	28-week period, 47 calls from general medical surgical wards.	Examination of case notes for documentation of abnormal physical signs and laboratory test results in the 24 hours before the call.	51% had premonitory signs. All patients with abnormal vital signs also had at least one abnormal laboratory value. Two thirds of patients were in hospital for more than 24h before arrest. Many cases no definitive action was promptly taken. Barriers identified regarding why attentive and capable individuals may fall short: Clinicians to busy and overwhelmed with information, inexperienced doctors do not appreciate how urgently some physical signs must be treated and they may feel they should be able to manage without seeking more expert help and supervision.	Level V
Smith, G., Prytherch, D., Schmidt, P. and Featherstone, P. (2008). Review and performance evaluation of aggregate weighted "track and trigger" systems. *Resuscitation, 77*, 170-179.	Database of 9,987 vital signs datasets	A systematic review of literature performed to describe ATWSS, their components and differences. Ability to discriminate between survivors and nonsurvivors using area under receiver operating characteristics (AUROC) curve.	33 unique AWTTS were identified with AUROC (+/- 95% CI) ranging from 0.657-0.782. 12 AWTTS (36%) discriminated reasonable well between survivors and nonsurvivors. The top 4 AWTTS incorporated age as a component. The top 2 also incorporated temperature.	Level IV

Smith, G., Prytherch, D., Schmidt, P., Featherstone, P. and Higgins, B. (2008). A review, and performance evaluation, of single-parameter "track and trigger" systems. *Resuscitation, 79*, 11-21.	Database of 9,987 vital signs datasets	A systematic review of literature performed to describe SPTSS, their components and differences. Sensitivity and specificity for predicting in hospital mortality when using admission vital signs from database.	Identified 39 unique classes of SPTTS, of which 30 evaluated. Considerable variation in physiological variables used and significant variation in physiologic values used to trigger medical emergency or critical care outreach team. Marked variation in sensitivity (7.3-52.8%), specificity (69.1-98.1%) , positive predictive value (13.5-26.1%) , negative predictive values (92.1-94.2%) and the potential number of calls triggered (234-3271)	Level IV
Smith, G., Prytherch, D., Schmidt, P., Featherstone, P., Kellett, J., Deane, B. and Higgins, B. (2008). Should age be included as a component of track and trigger systems used to identify sick adult patients? *Resuscitation, 78*, 109-115.	Database of 9,987 vital signs datasets	Studied relationship between admission vital signs and in hospital mortality for a range of selected vital signs, grouped by patient age. Used vital signs data set to study impact of patient age on relationship between patient triggers using MET criteria and MEWS and in hospital mortality.	Age has a significant impact on in hospital mortality. Inclusion of age in track and trigger systems could be advantageous in improving function. Mortality was higher as patient age increased. For each age group, mortality increased as total MEWS score increased.	Level IV
Tarassenko, L., Hann, A. and Young, D. (2006). Integrated monitoring and analysis for early warning of patient deterioration. *British Journal of Anaesthesia, 97* (1), 64-68.	690 BioSign alerts in total, reviewed by senior clinicians	BioSign fuses the vital signs in order to produce a single parameter representation of patient status, the Patient Status Index	BioSign alerts were generated, on average; every 8 hours: 95% of these were classified as "true" by clinical experts. Retrospective analysis has shown the data fusion algorithm is capable of detecting critical events in advance of single channel alerts.	Level IV

Intervention Studies					
Citation	**Sample**	**Intervention**	**Method**	**Findings**	**Evidence Grade**
Hillman, K., Chen, J., Cretikos, M., Bellomo, R., Brown, D., Doig, G., Finfer, S. and Flabouris, A. (2005). Introduction of the medical emergency team (MET) system: a cluster-randomized controlled trial. *Lancet*, 2091-2097.	23 hospitals randomized to receive introduction of MET system or controls-12 hospitals allocated MET system, 11 hospitals allocated to control.	Introduction of MET system	MET system activated in intervention hospitals and made available hospital wide for 6 month study period.	MET system greatly increased emergency team calls, but did not substantially affect the incidence of cardiac arrest, unplanned ICU admission or unexpected death. Unplanned ICU admission group-50% had documented calling criteria more than 15 minutes before the event, only 30% of these patients had an emergency team called.	Level II
Mitchell, I., McKay, H., Van Leuvan, C., Berry, R., McCutcheon, C., Avard, B., Slater, N., Neeman, T. and Lamberth, P. (2010). A prospective controlled trial of the effect of a multi-faceted intervention on early recognition and intervention in deteriorating hospital patients, *Resuscitation*, *81*, 658-666.	Consecutive adult patients admitted to four medical/ surgical ward during 4-month period, 1,157 and 985 subjects respectively before and after intervention.	Introduction of a multi faceted intervention (newly designed ward observation chart for vital signs, a track and trigger system and an associated education program) to detect clinical deterioration	Need for informed consent waived by Australian Capital Territory and Calvary Health Care ACT Health and Research Ethics Committee. Outcomes tracked were unplanned ICU admission, MET reviews/activations, unexpected hospital deaths	Reductions in unplanned admissions to ICU (1.8% versus 0.5%) and unexpected hospital deaths (1.0% versus 0.2%) during intervention period. Medical reviews increased for patients with significant clinical instability (43.6% versus 69.6%) and number of patients with MET activation increased (2.2% versus 3.9%). Mean daily frequency of documentation of vital signs increased during intervention period (3.4 versus 4.5, p=0.0001)	Level II
Priestley, G., Watson, W., Rashidian, A., Mozley, C., Russell, D., Wilson, J., Cope, J., Hart, D., Kay, D., Cowley, K. and Pateraki, J. (2004). Introducing critical care outreach: a ward – randomized trial of phased introduction in a general hospital. *Intensive Care Medicine*, *30*, 1398-1404.	All patients admitted to 16 acute adult wads of one general hospital over 32-week period. Dataset 1 included 7171 patients and Dataset 2 included 2792 patients.	Phased introduction of critical care outreach service	Pragmatic ward (cluster)-randomized design with phased introduction of intervention –by end of study all 16 wards included	Statistically significant reduction of in hospital mortality in ward where the service operated compared with those where it did not.LOS findings equivocal (possible increase in LOS not supported by confirmatory and sensitivity analysis)	Level II

Other Related Papers		
Citation	**Paper Type**	**Findings/Conclusions/ Recommendations**
Cuthbertson, B. (2008). Editorial-Optimizing early warning scoring systems. *Resuscitation, 77,* 153-154.	Editorial in Resuscitation	Four self assessment questions posed: 1. Does the early warning system I use in my clinical practice utilize and suitably weight early signs of deterioration such as heart rate and respiratory rate? 2. Does the early warning system I use in my clinical practice avoid giving disproportionate weight to late signs of deterioration such as blood pressure? 3. What is the diagnostic accuracy of the early warning score I use in my clinical practice in the populations in which I use it, and can it be improved? 4. What is the optimal cut point for the early warning score I use in my clinical practice and do I use this as the trigger for activating a response?
Smith, G., Prytherch, D., Schmidt, P., Featherstone, P., Knight, D., Clements, G. and Mohammed, M. (2006). Hospital-wide physiological surveillance-a new approach to the early identification and management of the sick patient. *Resuscitation, 71,* 19-28.	Clinical paper describing a system for collecting routine vital signs data at the bedside using standard personal digital assistants. Early warning systems are made immediately available to care providers along with other relevant clinical data. Potential tie to activation of rapid response team or primary care providers described.	Capturing physiological data at the bedside and making those data available to pertinent care providers or care systems (e.g. rapid response teams) at times proximal to collection of data and electronic dispatching of data to PDAs could impact outcomes.

Appendix C

Scoring system combining original MEWS, minus AVPU score, and addition of age score and body mass index score

	3	2	1	0	1	2	3
Systolic Blood Pressure (mmHg)	< 70	71-80	81-100	101-199		≥ 200	
Heart Rate (bpm)		< 40	41-50	51-100	101-110	110-129	≥ 130
Respiratory Rate (bpm)		< 9		9-14	15-20	21-29	≥ 30
Temperature (ºC)		< 35		35-38.4		≥ 38.5	
Age (y)					65-74	75-84	≥ 85
BMI (kg/m²)			< 18.5		25.1-34.9	> 35	

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