Measuring tele-ICU impact: does it optimize quality outcomes for the critically ill patient?

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Introduction

Grouping highly vulnerable patients together with resources is one strategy to improve patient outcomes, and is a model familiar in the world of hospital care. Some believe the birth of the modern intensive care unit (ICU) can be traced to the shock wards designed to resuscitate and care for injured soldiers during World War II (Calvin et al. 1997), or in response to the polio epidemic that raged throughout Europe and the USA during the late 1940s and early 1950s (Fisher 1997). Far earlier in history, Florence Nightingale advocated grouping vulnerable patients requiring intensive nursing and medical vigilance (Munro 2010) in an effort to improve the quality of patient care and patient outcomes. Since the onset of ICUs, the number of ICU beds...
has proliferated dramatically in response to the complexity of patient needs but are still expected to be woefully inadequate in the face of the health-care needs of an aging population (Amaral & Rubenfeld 2009, Vincent 2010, Evans et al. 2011). This access issue will require hospitals to either build additional ICU beds at steadily rising costs or find strategies to further support care outside of the traditional models. Conventional care is further tested by the shrinking pool of expert critical-care practitioners thus challenging specialist access for many underserved areas, including rural and community hospitals (Irwin et al. 2004, Buerhaus et al. 2009). The collision between the anticipated increased demand for service and the projected reduction in resources has spurred a surge of innovations in care with a focus on technology, the leveraging of resources and the ability to improve the quality of care (Joynt & Kimball 2008, Amaral & Rubenfeld 2009).

Through exploration of the research evidence, this commentary paper endeavours to demonstrate the potential role of the tele-ICU as an effective tool for the enhancement of critical-care quality with simultaneous leveraging of scarce resources.

The marriage of telemedicine and critical care

For over 25 years, telemedicine has provided an alternative solution to service access challenges by permitting remote physician-to-patient consultation. The term, telemedicine describes medical services being delivered over distance using communication technologies to improve the patient’s health status (American Telemedicine Association 2010). It can range from the simple, the use of the telephone to provide consultative services, to the complex, with the provision of surgery using highly complex virtual reality technologies. Tele-presence modalities (technologies that provide the appearance of being present) have provided a proven solution to specialty access issues for critically ill populations including neonates (Rendina 1998), trauma patients (Ricci et al. 2003) and critically ill or injured paediatric patients (Marcin et al. 2004) by using telemedicine for point-to-point medical consultation. Grundy et al. (1982) was the first to describe the value of intermittent remote telemedicine consultation for improving care in inpatient ICU patients. Nearly two decades passed before investigators at the Johns Hopkins University School of Medicine (Baltimore, MD, USA) used continuous remote ICU care to demonstrate a reduction in severity adjusted ICU and hospital mortality rates (Rosenfeld et al. 1999), therefore leading the way to the development of the tele-ICU solution [commonly referred to as the eICU® (trademark of Philips-VISICU, Baltimore, MD, USA), virtual ICU or remote ICU].

The tele-ICU model

The tele-ICU links intensivists (physicians’ board certified in the care of critically ill patients) and other critical-care practitioners to a network of audiovisual communication and computer systems to enable population-based care to geographically disparate ICUs (Jarrah & Van der Kloot 2010). Patient data are available and transferred via high-speed, protected connections to and from the centralized tele-ICU team. Two-way, high-resolution and zoom video cameras with microphones and speaker systems provide the tele-ICU with real-time patient assessment capabilities and/or communication links with the bedside team. Continuous monitoring of the patient status occurs through virtual rounds in which the tele-ICU registered nurse (RN) or physician reviews patient-specific data including laboratory results, vital signs, radiology images, medications and current clinical documentation assessing for subtle changes that may herald a change in patient status (Goran 2010). Vendor-specific software programs may provide a sophisticated alert system further encouraging the tele-ICU team to investigate clinical changes. Currently, there are approximately 45 tele-ICU programmes in the USA covering over 200 hospitals and providing care to approximately 10% of all critically ill patients. By 2009, over one million patients in the USA had received care through the tele-ICU system (Lilly & Thomas 2010).

Leveraging resources to enhance access

The primary purpose for the implementation of a tele-ICU is twofold: (1) the leveraging of scarce critical-care resources in the face of increasing provider shortages (Jarrah & Van der Kloot 2010) and (2) to effect improvements in the quality and safety of patient care (Rufo 2011a).

Early in the previous decade, data emerged supporting the role of the intensivist as a key variable in the determination of critical care patient outcomes (Pronovost et al. 1999, 2002, Dimick et al. 2001a). Despite the importance of the intensivist in improving patient care outcomes, few ICUs are able to provide intensivist care to their patients because of significant physician shortages and/or misdistribution: future resources are still expected to be insufficient to meet the population surge (Pronovost et al. 2002). Hospitals in the USA also face
additional pressure from the ‘Leapfrog’ recommendation for increased ICU physician staffing. The Leapfrog Group comprises an advisory board of Fortune 500 companies that regulate annual purchasing standards worth over $59 billion and have identified evidence-based recommendations for improving patient quality while reducing costs (Manthous 2004). Only 30% of ICUs in the USA are currently able to adhere to the Leapfrog Group recommendation for intensivist staffing (Sapirstein et al. 2009) and predicted intensivist shortages indicate continuing challenges in meeting this recommendation. A collaborative report, ‘The Critical Care Workforce: A Study of the Supply and Demand for Critical Care Physicians’ from the US Health Resources and Services Administration (2007) and the American College of Chest Physicians (ACCP) predict a 1500-intensivist shortfall in the USA by the year 2020.

Calculation of intensivist shortages outside of the USA is challenging as data is not always available, up-to-date or consistent in definition; neither is there any gold standard for assessing sufficiency (Kuehn 2007). The ‘World Health Report: Working Together for Health’ (World Health Organization 2006) predicts an estimated shortage of almost 4.3 million physicians and other health-care workers worldwide by 2015, with the greatest shortages occurring in South-East Asia, and in sub-Saharan Africa. Current human resource shortages, including intensivists, are mentioned as one variable influencing critical care rationing in many industrialized countries (Evans et al. 2011), thus suggesting a potential influence on critical care access and outcomes in the future.

Use of the tele-ICU can help mitigate access issues related to intensivist shortages. With the use of tele-medicine technology and team support, each tele-ICU intensivist typically monitors up to 150–200 patients (Goran 2011) in rural, regional, and academic/tertiary centres providing intensivist access and care to many underserved populations.

The tele-ICU also provides an opportunity to leverage experienced critical care nurses. In the USA, the predicted nursing shortage appears to have been momentarily derailed by the economic downturn. However, shortages are still expected in the next decade, further influenced by the decreased capacity for nursing education (Buerhaus et al. 2009). The increased need for RN positions is already prominent. The American Association of the Colleges of Nursing noted in the on-line nursing shortage fact sheet (AACN, Available at: http://www.aacn.nche.edu/, accessed 20 October 2011) the US Bureau of Labor Statistics confirmed that in April, 2011 283 000 jobs were added in the health-care sector within the previous year, with the largest segment going to RN positions. Projections of the severity of the nursing shortage are not unique to the USA. The nurse-to-population ratio varies in different countries from less than 10 nurses per 100 000 population to more than 1000 nurses per 100 000. Ratios in Europe are 10 times that of Africa and South East Asia, and the average ratio in North America is 10 times that in South America (International Council of Nurses 2006). Suboptimal nurse-to-patient ratios are linked to untoward patient outcomes including an increase in medication errors (Camire et al. 2009), increased pulmonary complications (Dimick et al. 2001b), and longer lengths of stay with higher complication rates (Needleman et al. 2002). Leveraging the experienced ICU nurse becomes important to the quality of the patient outcome.

Unlike their ICU colleagues providing direct patient care at the bedside to one or two patients in an assignment, the tele-ICU nurse monitor 30–40 ICU patients (Goran 2011). As with the bedside RN, the tele-ICU nurses assess patient needs but with the aid of technology to perform virtual rounding, video assessment, alert investigation and direct communication with the bedside RN. The experienced tele-ICU nurse is often available 24/7 to provide direct nurse-to-nurse consultation and mentoring, which is especially valuable on the evening or night shifts when fewer in-house resources are available.

Some tele-ICUs also use additional resources such as critical care pharmacists (Forni et al. 2010), educators (Barden 2010) and advanced practice nurses (Lilly et al. 2011) to provide care to critically ill patients in a variety of settings within their programme parameters.

**Tele-ICU quality enrichment**

The requirement for health-care institutions to demonstrate their ability to provide quality care at the lowest cost has never been more important. Performance, as measured in quality of care, is publicly reported and financial incentives are tied to quality improvements (Rufo 2011a). Commercial vendors of tele-ICU systems market their programmes based on the ability to improve the quality of ICU patient care, as demonstrated by improved outcomes. Initial tele-ICU outcome data has been somewhat sparse with much reported as abstracts, or conference abstracts with fewer scientifically rigorous, peer-reviewed studies available. The tele-ICUs’ ability to improve quality can be illustrated based on key outcome markers including: (1) clinical measures such as severity adjusted mortality and length of stay (LOS), and adherence to Best Practice recommendations; (2) financial outcomes; and (3) customer satisfaction.
The impact on key outcome markers: mortality and length of stay

Scoring systems based on physiological variables are used to measure severity of illness in the critically ill patient and provide for risk stratification in outcome comparisons. The Acute Physiology and Chronic Health Evaluation (APACHE IV®) generates severity-adjusted mortality and length of stay (LOS) predictions based on the acute physiology score in conjunction with the admission source, admission diagnosis, age and chronic health items and is commonly used to measure ICU performance (Zimmerman et al. 2006). By comparing actual with predicted outcome data, hospitals can compare performance in a single ICU over time, with other ICUs within a system, or with national standards.

A number of organizations (Zawada et al. 2006, Howell et al. 2007, 2008, Kohl et al. 2007b, Van der Kloot et al. 2009, Thomas et al. 2009, Zawada et al. 2009, McCambridge et al. 2010, Lilly et al. 2011, Wood et al. 2011) have published pre-/post-tele-ICU implementation comparisons using data demonstrating the impact of the tele-ICU programme on the APACHE ICU and hospital mortality and LOS (Table 1). Table 1 summarizes the pre- and post-tele-ICU comparison studies on adult severity adjusted patient ICU/hospital mortality and LOS. Despite some rather compelling data, the association between the tele-ICU and the APACHE outcomes remains somewhat unclear (Morrison et al. 2010). Complicating the picture of data review and meta-analysis is a number of factors including: (1) variation in how tele-ICU coverage is defined, (2) the type of hospitals where the evaluation occurred and (3) the various impacts of the tele-ICU coverage (Young et al. 2011a). Others (Davis & Jackson 2010) cite the need for a more rigorous assessment of specific tele-ICU care elements with ‘sequential and parallel hypothesis testing’ especially given the cost requirements of the tele-ICU model. Yoo and Dudley (2009) point to the ‘lack of conceptual framework of what ICU care is’ as a complicating variable in the research, especially as it relates to the impact of the tele-ICU on mortality and LOS. However, the majority of the comparison data does suggest that tele-ICU care is linked with improved patient mortality (Fifer et al. 2010).

The impact on key outcome markers: best practice compliance

As patient care continues to increase in complexity, not only has there been additional emphasis on evidence-based care, but also the additional mandate for the right care in a timely manner (Ries 2009). As such, the ongoing efforts to comply with key bundles/protocols believed to reduce the incidence of ventilator acquired pneumonia (VAP) or sepsis remain two examples of the necessity of providing compliance for each step of the bundle. Partnerships between the tele-ICU and the bedside team have proven effective for many organizations (Table 2) in improving sepsis bundle compliance (Ikeda et al. 2006, Patel et al. 2007, Rincon et al. 2007a,b), reducing cardiorespiratory arrests in ICU patients (Shaffer et al. 2005) and improving glycaemic control (Aaronson et al. 2006, Cowboy et al. 2011a). Other tele-ICU/ICU collaborations have demonstrated improved outcomes related to the support of rapid response teams (multidisciplinary in-hospital teams designed to recognize early signs and symptoms of deterioration in a patient’s condition, and act to prevent a worsening patient crisis) resulting in fewer codes outside of the ICU (Youn 2006), improved Deep Vein Thrombosis (DVT) prevention (Giessel & Leedom 2007, Cowboy et al. 2011b), prevention of air embolisms (Cowboy et al. 2009a), improved compliance for timely referral and organ procurement (Cowboy et al. 2009b) and a reduction in ventilator use and/or ventilator days (Cowboy et al. 2006, McCambridge et al. 2010). Unfettered by many of the distractions common to the ICU environment, the tele-ICU reviews and evaluates the individual patient plan of care during virtual rounds and audits bundle compliance. An omission can be brought to the attention of the bedside team for resolution, or the tele-ICU physician can enter the necessary physician orders for compliance attainment. For example, Advocate Healthcare System (Chicago, IL, USA) with over 16 300 ICU admissions per year, provided data from their tele-ICU system illustrating the tele-ICU role of screening all mechanically ventilated patients twice per day for compliance with the VAP bundle. When a component of the bundle was missing, the tele-ICU intensivist would either enter the necessary order or notify the bedside to address the oversight. Since the initiation of this process, the compliance to the bundle has increased to 99%, with a significant reduction in VAP from 2004 to 2007 (Ries 2009).

The impact on key outcome markers: fiscal return

With the promise of improved patient outcomes comes the expectation of cost savings related to reductions in LOS and/or complication rates or improved ICU capacity. Length of stay is the most important determinant of ICU variable cost (Rapoport et al. 2003) so
<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Study description</th>
<th>Outcome</th>
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</table>
| Lilly et al. (2011) | Prospective stepped-wedge clinical practice study of 6290 adults admitted to seven ICUs from April 2005 to September 2007 | Hospital mortality: non-tele-ICU group 13.6%; tele-ICU group 11.8%; statistically significant $P = 0.005$  
ICU mortality: non-tele-ICU group 10.7%; tele-ICU group 8.6%; statistically significant $P = 0.003$  
Hospital LOS: non tele-ICU group 13.3 days; tele-ICU group 9.8 days; statistically significant, $P < 0.001$  
ICU LOS: non tele-ICU group 6.4 days; tele-ICU group 4.5 days; statistically significant, $P < 0.001$ |
| Young et al. (2011a,b) | Systematic review of 13 studies that reported outcomes of ICU and in-hospital mortality and ICU and hospital LOS | Hospital mortality: decrease 0.82 to 0.65; not statistically significant; $P = 0.08$  
ICU mortality: statistically significant reduction from ratio 0.80 to 0.66; $P = 0.02$  
Hospital LOS: mean reduction of 0.64 days; not statistically significant, $P = 0.16$.  
ICU LOS: mean reduction 1.26 days, $P = 0.01$ |
| Wood et al. (2011) | Pre-/post-tele-ICU implementation review in two ICUs using APACHE IV at 1 year | Hospital mortality: pre-implementation 0.99; post-implementation 0.7  
ICU LOS: pre-implementation 6.79 days; post-implementation 4.96 days |
| McCambridge et al. (2010) | Evaluation of the effect of a health information technology bundle and remote intensivist coverage at night on mortality: pre-implementation 954 control patient over 16 months; post-implementation 959 patients over 10 months | Hospital mortality: pre-implementation 21.4%; post-implementation 14.7%; statistically significant; $P < 0.001$ |
| Zawada et al. (2009) | Pre-implementation (2004) and post-implementation (2005–2007) comparisons in regional and tertiary hospital observations: 2793 patient observations in the three regional hospitals; 2833 patient observations for the tertiary hospital | Regional Hospitals (3) Outcomes  
Hospital mortality: rates pre-implementation 4.7%, 4.8%, 9.6%; post-implementation 4.4%, 6.1%, 5.9%.  
Hospital LOS (actual–to-predicted ratio):  
pre-implementation 0.67, 0.79, 0.79;  
post-implementation 0.64, 0.65, 0.74.  
Tertiary Hospital Outcomes  
Hospital mortality (actual–to-predicted ratio):  
pre-implementation 0.62; post-implementation 0.56  
Hospital LOS (actual–to-predicted ratio):  
pre-implementation 0.92; post-implementation 0.75  
Hospital mortality: Pre-implementation 12.0%; Post-Implementation 9.9%; not statistically significant, $P = 0.03$  
ICU mortality: pre-implementation 9.2%; post-implementation 7.8%; not statistically significant, $P = 0.12$  
Hospital LOS: pre-implementation 9.8 days; post-implementation 10.7 days  
ICU LOS: pre-implementation 4.3 days; post-implementation 4.6 days |
| Thomas et al. (2009) | Observational study in six ICUs at five hospitals including 2034 patients in pre-implementation period and 2108 patients in post-intervention comparison | Hospital mortality: trend towards improvement, $P = 0.214$  
ICU mortality: trend towards improvement, $P = 0.159$  
Hospital LOS (actual/predicted ratio):  
pre-implementation 0.97; statistically significant, $P = 0.001$; post-implementation 0.32  
ICU LOS (actual/predicted ratio): pre-implementation 0.84; post-implementation: 0.56; statistically significant, $P < 0.001$ |
pre-implementation 0.92; post-implementation 0.74 |
| Howell et al. (2008) | Pre-implementation and Post-implementation comparison of mortality and LOS: 1 year pre-implementation with 700 patients; 2 years post-implementation with 4592 patients | Hospital mortality: trend towards improvement, $P = 0.214$  
ICU mortality: trend towards improvement, $P = 0.159$  
Hospital LOS (actual/predicted ratio):  
pre-implementation 0.97; statistically significant, $P = 0.001$; post-implementation 0.32  
ICU LOS (actual/predicted ratio): pre-implementation 0.84; post-implementation: 0.56; statistically significant, $P < 0.001$ |
| Kohl et al. (2007a,b) | Retrospective evaluation of data for 2811 patients over 3 years | Hospital mortality: pre-implementation 11.1%; post-implementation 6.0%  
Hospital LOS: pre-implementation 11.0 days (median); post-implementation 9.2 days (median) |
tele-ICU systems that reduce the ICU LOS should be associated with organizational savings. However, a reduction in ICU LOS does not simply equate to a reduction of average costs for the saved days as most hospitals cannot accurately determine where all their costs originate (Ries 2009). Moreover, variations in cost structures and severity of illness further contribute to the challenge (Zawada et al. 2009). Even with reductions in LOS, cost savings can only be realized if organizations can modify staffing levels to the patient census. In addition, consideration must be given to the percentage of ICU patients subject to case rate reimbursement, especially given the large number of patients in the USA covered by the Medicare system (Zawada et al. 2009). Yet hospital executives are calling for data demonstrating return on investment (ROI) to assign value for the tele-ICU programme. Few organizations have been as successful as the Resurrection HealthCare (RHC, Chicago, IL, USA) tele-ICU programme in demonstrating this type of fiscal impact. The RHC tele-ICU monitors 185 critical care beds in 10 hospitals. Within the first 6 months after tele-ICU implementation, a cost savings of $3 million was attributable to LOS reductions and approximately $5 000 000–6 000 000 savings in preventable claim settlements when compared with pre-implementation data (Zapatochny Rufo 2009).

Savings may also be appreciated with a reduction in the patient complications frequently experienced in the ICU, for example VAP. As discussed previously, Advocate HealthCare experienced a sevenfold reduction in VAP cases when the ICU was supported in reduction strategies by the tele-ICU programme. This reduction of 87 fewer VAPs translated into a saving of $2 449 833 over a 3-year period (Ries 2009). Reductions in catheter-related bloodstream infections or acute kidney injury for ICU patients associated with a tele-ICU may provide further opportunities for cost savings (Lilly et al. 2011).

The complexities highlighted in establishing the ability of the tele-ICU to demonstrate financial return can be witnessed in the modest number of published studies (Table 3). Published reports of the cost reductions which have occurred with tele-ICU implementation are summarized in the Table 3 and demonstrate the ability to see ROI based on savings from LOS reductions, transport costs, pro-fee billing charges capture and the cost savings from the use of a tele-pharmacist. Despite the difficulties associated with demonstrating potential savings, the cost of quality as a determination of value will only become more important as financial incentives are tied to quality improvements (Rufo 2011a). As such, tele-ICUs must continue to explore options for demonstrating the impact on quality as a cost-effective measure.

### The impact on key outcome markers: customer satisfaction

The customers of the tele-ICU services include the health system, the individual hospital, the ICU team (staff and providers), the critically ill patient and family members, and others as defined by programme goals. Although health systems may invest millions of dollars in the tele-ICU programme as a strategy to improve patient care quality, they would be naive to believe that the quality outcomes will improve without the acceptance and cooperation of the ICU team. Numerous articles and authors (Badawi 2006, Breslow 2007, Tang et al. 2007, Zapatochny Rufo 2007, Myers & Reed 2008, Lilly & Thomas 2010, Ries 2009, Zawada et al. 2009, Chu-Weininger et al. 2010, Goran 2010, Jarrah & Van der Kloot 2010, Young et al. 2011a,b) have

### Table 1

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<thead>
<tr>
<th>Author (year)</th>
<th>Study description</th>
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<tbody>
<tr>
<td>Howell et al. (2007)</td>
<td>Pre- and post tele-ICU implementation of APACHE III: 84 ICU beds over five quarters (2006–2007)</td>
<td>Hospital mortality (actual–to-predicted ratio): pre-implementation 0.95 ($P = 0.02$); post-implementation 0.77 ($P &lt; 0.001$); Hospital LOS (actual–to-predicted ratio): pre-implementation 1.09 ($P &lt; 0.001$); post-implementation 0.84 ($P &lt; 0.001$)</td>
</tr>
<tr>
<td>Breslow et al. (2004)</td>
<td>Pre- and post-implementation comparison of tele-ICU mortality outcomes in two adult ICUs using APACHE III</td>
<td>Hospital mortality: statistically significant reduction, $P &lt; 0.05$; ICU mortality: statistically significant reduction, $P &lt; 0.05$</td>
</tr>
<tr>
<td>Rosenfeld et al. (1999)</td>
<td>Single, 10-bed surgery/trauma ICU Community hospital Outcomes severity adjusted</td>
<td>Hospital mortality: 30% reduction; ICU mortality: 45% reduction; ICU LOS: 16% reduction</td>
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</tbody>
</table>

APACHE, Acute Physiology and Chronic Health Evaluation.
reinforced the necessity of the ICU/tele-ICU collaboration in achieving the best patient outcomes. Successful collaboration requires mutual respect and acceptance for the role of the tele-ICU by the bedside team. The addition of the tele-ICU team as care partners can be either reassuring or threatening to the ICU (Zapatochny Rufo 2007). Response is determined by the culture of the ICU, the commitment of the leadership and the organizational messages regarding the role of the tele-ICU in achieving quality goals (Goran 2010). The required interdependence can be a barrier to effective implementation or further expansion of the tele-ICU system (Breslow 2007, Zapatochny Rufo 2007, Myers & Reed 2008, Lilly & Thomas 2010, Ries 2009, Zawada et al. 2009, Chu-Weininger et al. 2010, Goran 2010, Jarrah & Van der Kloot 2010, Young et al. 2011b, Mullen-Fortino et al. 2012). Researchers (Young et al. 2011b) performing a systematic review of the literature, examined tele-ICU acceptance among physicians in 16 studies, nurses in 13 studies and hospital administrators in one study. Four studies specifically examined ICU satisfaction using a five-point Likert scale (1 = poor acceptance, 5 = high satisfaction); the mean satisfaction ranged from 4.22 to 4.53, indicating a favourable acceptance. The authors concluded, ‘Staff generally viewed tele-ICU coverage as improving ICU quality despite initial reservations’. In a pre- and post-implementation comparison using a non-scaled validated survey tool, researchers (Chu-Weininger et al. 2010) measured the impact of the tele-ICU on ICU attitudes regarding teamwork and the safety climate. They hypothesized that with the immediate access to

### Table 2
Tele-intensive care unit (ICU) impact on clinical indicators of quality

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<tr>
<th>Author (year)</th>
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<th>Outcome</th>
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<tbody>
<tr>
<td>McCambridge et al. (2010)</td>
<td>Impact of health information technology bundle and remote intensivist coverage during the night; what is the impact on ventilator and vasopressor use?</td>
<td>Ventilator use was significantly less (P = 0.0001 when controlled for severity of illness; no significant difference in vasopressor use with the tele-ICU</td>
</tr>
<tr>
<td>Cowboy et al. (2009a,b)</td>
<td>Use of the tele-ICU coaching and documentation to demonstrate compliance with Trendelenburg position for removal of a central venous line from intubated patients</td>
<td>With tele-ICU monitoring, mentoring and intervening capabilities has resulted in preventing three potential cases of air embolism during the first 2 months of use</td>
</tr>
<tr>
<td>Cowboy et al. (2009a,b)</td>
<td>Use of tele-ICU to assist in compliance with requirements to contact the Midwest Transplant Network within the allotted time during an imminent death</td>
<td>A 2-year collaboration between the tele-ICU and bedside team has resulted in a significant increase from 45 to 92% notification</td>
</tr>
<tr>
<td>Patel et al. (2007)</td>
<td>Determine the role of the tele-ICU on the identification of the patient with severe sepsis and adherence to the bundle requirements</td>
<td>Tele-ICU monitoring may improve overall compliance with the resuscitation sepsis bundle</td>
</tr>
<tr>
<td>Giessel and Leedom (2007)</td>
<td>A comparison of adherence to deep vein thrombosis (DVT) prevention compliance with process-directed care from the tele-ICU</td>
<td>Improved compliance with DVT prophylaxis is obtained when these process activities are coordinated from a central location.</td>
</tr>
<tr>
<td>Rincon et al. (2007a,b)</td>
<td>Tele-ICU screened high risk patients in eight hospitals; tracked for compliance with the sepsis bundle therapy either initiated by the tele-ICU intensivist or ICU physician contacted directly</td>
<td>With tele-ICU support, sepsis bundle compliance increased significantly. Remote identification of at-risk patients may be beneficial for improving adherence to best practice</td>
</tr>
<tr>
<td>Rincon et al. (2007a,b)</td>
<td>Use of tele-ICU in defining true incidence of severe sepsis using electronic screening for 161 ICU beds in 10 hospitals</td>
<td>Data suggests that the incidence for severe sepsis is higher than what has been previously reported. Identifying and targeting this population for timely intervention will have a significant impact on the survival of at risk patients.</td>
</tr>
<tr>
<td>Youn (2006)</td>
<td>Impact of tele-ICU intensivist support on hospital rapid response teams (RRT) and patient outcome</td>
<td>Tele-ICU support of RRT positively affected preliminary data on out of unit cardiac arrest, codes per 1000 discharges and nursing satisfaction</td>
</tr>
<tr>
<td>Aaronson et al. (2006)</td>
<td>Impact of the tele-ICU programme on glycaemic control in seriously ill patients</td>
<td>The tele-ICU programme improved best practice outcomes in rural hospitals by reducing the average glucose levels from 161 to 139 mg/dl</td>
</tr>
<tr>
<td>Ikeda et al. (2006)</td>
<td>Tele-ICU support for adherence to the Surviving Sepsis 6-hour and 24-hour bundles to reduce mortality</td>
<td>Shared patient management between the tele-ICU and ICU improved compliance with the 6-hour and 24-hour bundles with a reduction in patient mortality</td>
</tr>
<tr>
<td>Shaffer et al. (2005)</td>
<td>Pre- and post-tele-ICU implementation impact on total code events, codes per patient, codes per patient day, initial resuscitation success and hospital discharge rates</td>
<td>Tele-ICU management was associated with a significant decrease in the number of cardio-respiratory arrests occurring in monitored ICU patients</td>
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</tbody>
</table>
tele-ICU intensivists, learning and overall safety and quality would improve while intimating that the ICU would struggle to ‘incorporate the new team member’. Results indicated an association between tele-ICU implementation and improved teamwork and safety climates, especially among the ICU nurses. Providers were more confident that their patients were adequately covered even then they were off the unit, felt it was easier to contact physicians for urgent issues and that they were not being interrupted unnecessarily. In a recent cross-sectional study (Mullen-Fortino et al. 2012), ICU nurses in three hospitals connected with a tele-ICU were asked to participate in a validated internet survey using a Likert-scaled response (i.e. strongly disagree, disagree, neutral, agree and strongly agree) to respond to both positive and negative statements regarding telemedicine in the ICU. Results pointed to a general support for the ICU telemedicine technology with the belief that telemedicine improves ICU survival. Respondents expressed some concerns about patient privacy and intrusion into the ICU workflow. Notably, ICU nurses expressed a desire to personally know the tele-ICU physician on duty, which is not always an option in tele-ICU. Other customer satisfaction surveys are summarized in Table 4. Conversely, studies in which ICU and provider acceptance of the tele-ICU is more limited or usage of tele-ICU service is discouraged, there is little evidence of any impact of tele-ICU on outcome indicators such as mortality and/or LOS (Zawada et al. 2009, Thomas et al. 2010, Young et al. 2011a,b).

Although patients and families are also affected by the role of the tele-ICU in patient care, there is meagre discussion in the literature related to their customer satisfaction. Jahrsdoerfer & Goran (2010), surveyed ICU patient family members in a multisite query to explore perceptions regarding the role of the tele-ICU in patient care. Data from 198 completed surveys from family members indicated a strongly affirmative response (79% positive, 2% negative and 19% neutral) to the use of the in-room cameras and the remote team in supporting the care of the patient. Open-ended family responses indicated the emergence of three themes in relation to their perceptions regarding the tele-ICU: (1) an increased sense of family comfort, (2) a positive impression related to the use of the technology in their local hospital, and (3) a sense of heightened safety for the patient. Given the emphasis on patient-/family-centred care, it is vital to continue research to validate the role of the tele-ICU on the patient/family experience.

As a new environment of practice for critical-care nurses, issues of tele-ICU internal satisfaction are also important to investigate. Nursing turnover from

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Type of cost savings</th>
<th>Monies saved</th>
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<tbody>
<tr>
<td>Zapatochny Rufo (2009)</td>
<td>Demonstrated ROI during the first 6 months of activation.</td>
<td>Decreased LOS by 38% translating into a $3 million savings; improved quality with avoidance of potentially paid settlement claims was approximated at $5–6 million savings</td>
</tr>
<tr>
<td>Zawada et al. (2009)</td>
<td>Calculated savings from reduction in ICU LOS using conservative range of cost structures</td>
<td>Cost savings of $8 million to rural system with tele-ICU system</td>
</tr>
<tr>
<td>Zawada and Herr (2008)</td>
<td>Pre- and post-comparison of transport costs from rural to tertiary care centre. Saved 160 transfers (most by helicopter)</td>
<td>$1 202 379 savings, which exceeded the expenditure for the program of these sites by more than $500 000</td>
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<td>Meidl et al. (2008)</td>
<td>Measured the impact of a tele-pharmacist on drug cost savings</td>
<td>Annual projected drug cost savings $489 100</td>
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<td>Rincon et al. (2007a,b)</td>
<td>Centralized remote data collection using advanced technology (APACHE III) can improve efficiency, accuracy and costs</td>
<td>Total estimated savings of $132 859 for 2007 and $318 248for 2008</td>
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<td>Kohl et al. (2007a,b)</td>
<td>Retrospective comparison of random sample of 189 patients pre-implementation and 2622 patients 3 years post-implementation in a surgical ICU 10% reduction in ICU stay and 20% reduction in floor stay post implementation</td>
<td>ICU savings of $706 272–941,697 and floor of $2 134 339–2 842 940</td>
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<td>Hine (2006)</td>
<td>Pro-fee billing charges capture Pre-implementation tele-ICU, capture was manual chart abstraction Post-implementation: no change in attending coverage or coding staff</td>
<td>Average pro-fee billing charge rose to $227 000/month, a 31% increase, $P = 0.004</td>
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ROI, return on investment; LOS, length of stay; APACHE, Acute Physiology and Chronic Health Evaluation.
dissatisfaction with working conditions can be frequent and expensive (Hayes et al. 2006, Jones & Gates 2007, Stone et al. 2007). The team relationship that develops within the tele-ICU team has been described as an ‘esprit de corps’ and ‘a true team’ (Stafford et al. 2008), and a ‘new paradigm of teamwork’ (Ries 2009). Researchers (Stafford et al. 2008) observed that tele-ICU nurses and physicians are ‘complimentary of each other and the value that their roles bring to the entire team’ and believe that these ‘unique and positive relationships are different from those relationships at the bedside’. Because the team often works in a fairly confined space with open work stations, discussion between the various team members occurs naturally with significant engagement (Stafford et al. 2008). Tele-ICU staff satisfaction tends to be positive for many reasons, including the reduction in physical and emotional stress, the sense of team and the prolongation of the career path of the experienced ICU nurse (Zapatochny Rufo 2007, Myers & Reed 2008, Stafford et al. 2008, Goran 2012). Given the challenge of recruiting the experienced critical-care nurses and intensivists required for the current tele-ICU models, particular attention must be paid to the relationship between tele-ICU models and satisfaction; however, it is challenging to find published studies measuring tele-ICU staff satisfaction. MaineHealth VitalNetwork (MHVN), a tele-ICU programme located in Portland, Maine, USA, and employer of this author, measured staff satisfaction via a survey tool in 2008, 2009 and again in 2011 to study the impact of various tele-ICU programme changes on staff satisfaction. Each staff member (number of participants varied from 28 to 33 in the three surveys) received an email link to the on-line survey in which they graded eight categories (Performing Meaningful Work, Communication, Work Environment, Autonomy, Work Schedule, Support of Supervisor and Coworkers, Stress/Pressure, and Relationships with Supervisor and

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<tr>
<th>Author (year)</th>
<th>Group measured</th>
<th>Conclusions</th>
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<td>Goran (2011)</td>
<td>Tele-ICU programmes: how is competency measured in the tele-ICU?</td>
<td>Competency assessment and validation occurs in the majority of current tele-ICU programmes even without specialty professional practice standards</td>
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<td>Chu-Weininger et al. (2010)</td>
<td>ICU nurses and physicians in three ICUs; measured teamwork and safety climate pre- and post-tele-ICU implementation</td>
<td>Implementation of a tele-ICU was associated with improved teamwork climate and safety, especially among nurses. Providers were also more confident about patient coverage and physician accessibility</td>
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<td>Young et al. (2011b)</td>
<td>Reviewed 23 studies grouped into four categories of staff evaluation, including overall acceptance, impact on patient care, impact on staff and organizational impact</td>
<td>Initial reports suggest high levels of staff acceptance of tele-ICU coverage</td>
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<td>Jahrsdoerfer and Goran (2010)</td>
<td>Perceptions of the role of the tele-ICU by family members of patients in the ICU</td>
<td>Family members are undereducated about the role of the tele-ICU in patient care Family members are overwhelming positive about the role of the tele-ICU for patient safety Residents perceive that this change in work flow is associated with improved patient safety and ‘demonstrated an innovative approach to critically ill patients’</td>
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<td>Coletti et al. (2008)</td>
<td>Resident perceptions of an integrated remote ICU monitoring system</td>
<td>Remote telemonitoring in a residency training programme was perceived by residents to have a substantial impact on their education and improved patient care</td>
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<tr>
<td>Mora et al. (2007)</td>
<td>Residents exposed to the telemonitoring system with tele-ICU support</td>
<td>Tasks fell into five major categories: patient monitoring, collaboration, system maintenance, health records maintenance and miscellaneous. Workflow interruptions and redirections affected the tele-ICU physician and nurses differently, with nurses interrupted more frequently ICU collaboration affects and quality and efficiency of the tele-ICU’s work</td>
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<tr>
<td>Tang et al. (2007)</td>
<td>Time-and-motion study of the tasks and activities of the tele-ICU nurses and physicians</td>
<td>Rotations in remote telemonitoring units should be included in training curriculum; enhances skills, prepares for the future, and ameliorates communication and professionalism</td>
</tr>
<tr>
<td>Faiz et al. (2006)</td>
<td>Sixteen Fellows who rotated through a tele-ICU program as part of their educational experience</td>
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Coworkers) for overall satisfaction (see Figures 1 and 2). Under each of the major categories, participants were asked to respond to a series of both positive and negative statements with rating selections from strongly agree, agree, neutral, disagree, or strongly disagree. In addition to the ratings, comment boxes were available for additional free-text remarks. In comparing the results of the three surveys, the ratings categories were summarized as strongly satisfied/satisfied (SS/S), neutral and dissatisfied/strongly dissatisfied (D/SD). Although satisfaction was already positive in 2008, the survey comparison demonstrated an increased satisfaction rate from 2008 to 2011 (82% response rate averaged over three surveys) in all categories. Under the working relationship category, comments and survey responses identified the relationship between the tele-ICU physicians and staff as the most important satisfier for the tele-RNs. In a reciprocal survey provided to the tele-intensivists by the medical director, the greatest satisfier according to physician response (Likert scale 1 = strongly dissatisfied, 5 = strongly satisfied) was the working relationship with the nurses (average score 4.56).

As resources become increasingly limited, research indicating which tele-ICU models are associated with the highest level of both staff satisfaction and patient outcomes may help guide organizations to design tele-ICU programmes with the best possible efficacy and team sustainability.

The role of the tele-ICU RN in patient safety: a quality indicator

The art of providing patient care while remote from the patient and family requires nurses to undergo a paradigm shift (Goran 2012). This is especially true for critical-care nurses who are used to providing on-site high-intensity/high-touch care for a very vulnerable group of patients and families. Tele-ICU nurses look to their professional organizations such as the American AACN, or the American Telemedicine Association (ATA) for guidance on professional standards, competency indicators and validation of the value of this emerging critical care subspecialty (Goran 2011). The AACN has responded to these needs with an announcement in 2011 providing experienced tele-ICU nurses a direct pathway to initial certification. Additionally, both AACN (Barden et al. 2010) and ATA (American Telemedicine Association 2008) have tele-ICU task forces which have been convened to explore the professional practice environment and to assist in meeting the professional needs of this critical-care group. However, tele-ICUs are exploring different opportunities to highlight the impact of tele-ICU RN care.

Story telling and the use of exemplars has been a time-honoured tradition in nursing and can be a powerful tool in assisting the listener and the storyteller in developing a shared knowledge and understanding (Maher 2003). Through conference participation, on-line discussions, and face-to-face forums, tele-ICU nurses have been sharing stories of their work to enhance a shared understanding with their ICU colleagues and to expand their professional identity. Some of these stories can be used to demonstrate competencies as defined in the AACN Synergy Model (Goran 2011), others are used to validate contributions to patient care and outcomes. As powerful as these stories may be to hear or to tell, data is required to measure the contributions of tele-ICU to the ICU patient outcomes. Mathers and Barden (2011) presented data at the 2011 HealthCare Information and Management Systems Society emphasizing the role of tele-ICU nursing interventions in impacting patient safety. Many tele-ICU use a software application pro-
vided by the vendor to enable the tele-RNs to contribute data into a national database detailing the nursing interventions. Using this application tool, interventions collected at a single tele-ICU were examined and classified into four categories (Barden et al. 2010):

- Rescue: patient in trouble, immediate action required
- Prevention: intervention that prevented occurrences such as falls, self-extubation, allergic reactions, etc.
- Assistance: interventions initiated by the tele-ICU RN.
- ‘First Aid’: nurse-to-nurse consultation (e.g. troubleshooting equipment, educating/coaching, answering clinical questions).

Of 593 interventions captured from September, 2008 to August, 2009, 51% of interventions were related to ‘assist’, 19.4% to ‘prevention’, 6% to ‘rescue’ and 23.6% to ‘first aid’. Types of interventions affecting patient safety included ‘falls prevented’, ‘code avoidance’, ‘intubation avoidance’, and others. Without the intervention of the tele-ICU nurse, any of the safety issues could certainly contribute to problematic patient outcomes and higher ICU costs. The identification of patient safety risks is a value-added service available from the tele-ICU that should not be overlooked, as noted in the example below.

A widely publicized case in January 2010 at Massachusetts General Hospital in Boston, MA, USA, indicated that the crisis alarm on a patient’s cardiac monitor was turned off; staff did not respond to numerous lower-level alarms warning of a low heart rate and the patient suffered from a fatal heart attack. This case prompted a Boston Globe investigation (Kowalczyk 2011) that analysed data from a Food and Drug Administration’s database of adverse events involving medical devices and found 216 deaths nationwide from 2005 to the middle of 2010 in which problems with monitor alarms occurred. In Massachusetts alone, at least 15 deaths in the past 6 years appear related to ‘missed’ alarms. Despite the collaboration between manufacturers and clinicians, no clear solution to the ‘alarm fatigue’ issue has been identified thus placing patients at continued risk (Kowalczyk 2011).

In the MHVN tele-ICU programme data review of interventions from January 1, 2011 to June 30, 2011, 60 tele-RN interventions were related to the identification of ‘alarms off’ at the bedside, an average of 10 per month. Upon identification of an ‘alarm off’, the tele-RN immediately notified the ICU bedside nurse for correction of the situation, thus preventing a potential life-threatening situation for the patient. In reviewing data from the national tele-ICU nursing intervention data involving 18 tele-ICU programmes from October 2010 to August, 2011, 749 instances of ‘ID alarms off’ were identified and reported by tele-ICU nurses (C. Barden, Clinical Nurse Specialist Tele-ICU, Baptist Health South Florida, Miami, FL, USA, personal communication, 30 September, 2011).

This data provided by the specific examples of tele-ICU nursing interventions suggests that the additional vigilance provided by the tele-ICU nurses directly enhances patient safety by preventing the potential patient harm and improving the quality of care.

**Conclusion**

The association between the tele-ICU and quality has been explored for over a decade, but the connection remains somewhat unclear. What is clear from study results is that the tele-ICU by itself may not be able to deliver the improvement in quality that many organizations seek. Plainly, the ability to affect patient outcomes and quality goals is dependent upon the collaboration and acceptance of the ICU team. However, the tele-ICU can still play a vital role in optimizing the quality of care being received by the critically ill patient. One value-added aspect of tele-ICU systems is that they are an ‘enabling technology’ (Miller 2009) meaning they require the development of broader care teams to affect work flow and communication. The tele-ICU cannot be taken out of the context of organizational efforts to improve quality. A broader vision of the incorporation of tele-ICU into critical care and organizational quality goals must occur, especially given the demands of the global health-care environment (Rufo 2011b). In JAMA editorial regarding the tele-ICU, Kahn states ‘Telemedicine alone does not equate to quality improvement but is merely a tool for quality improvement’ and concluded, ‘... in the right setting and with the right goals, telemedicine can indeed be used to help improve outcomes’ (Kahn 2011).

**Implications for nursing management**

Nursing leadership is vital in optimizing the effectiveness of the tele-ICU (Zapatachny Rufo 2007). Nursing leaders can provide the bedside team with the necessary context by translating the organizational vision of quality into practice while describing how the tele-ICU can assist in achieving improved patient outcomes. Key messages from the chief nursing executive should include expectations of ICU cooperation and collaboration with the tele-ICU. Nursing concerns such as the
consequences of the in-room camera on patient and staff privacy, workflow interruptions, potential conflict between the bedside physician and the tele-intensivist, and concerns about job security should be anticipated (Goran 2010, Mullen-Fortino et al. 2012). The ICU staff should be encouraged to express their fears and concerns and, once identified, strategies to provide accurate and timely information to alleviate fears should be developed and implemented. Strategies such as visiting and observing care in the tele-ICU, having the tele-ICU nursing manager/director attend ICU staff meetings or question/answer forums and providing tele-ICU–ICU nurse liaison partnerships (Goran 2010) have been successful integration strategies for many ICUs. Nursing leaders from both the ICU and tele-ICU must model the collaborative and communication behaviours desired from the nursing staff and physicians.

Once the ICU joins the tele-ICU programme, integration of the ICU and tele-ICU staff requires relationship-building over time (Zapatachny Rufo 2007, Myers & Reed 2008, Chu-Weininger et al. 2010, Goran 2010, Mullen-Fortino et al. 2012). Joint events such as educational offerings, staff meetings or quality team meetings can provide a forum in which both staffs can identify problems and possible solutions, or share patient stories. Combined celebrations provide a less formal opportunity to strengthen the sense of team and establish dual ownership for patient care and outcomes. Collecting data on the number of tele-RN and physician interventions and staff satisfaction may provide quantitative data to measure engagement and growth of the relationship over time. Significant opportunities for tele-ICU research continue and nursing leaders should encourage and support a sense of inquiry regarding the tele-ICU (Goran 2010) as tele-ICU practice continues to emerge as a subspecialty.

Telemedicine is perceived as one solution for meeting current and future health-care needs and further enhancement is playing a major role in the planning of both public and private agencies responsible for the health of its populations (Latifi et al. 2006, Durrani et al. 2009, Farrell 2011, Nesher & Jotkowitz 2011, Shahpori et al. 2011). As with the realization of the tele-ICUs as part of the delivery model for critical care, excellence in nursing leadership will be required to lead further telemedicine innovation and to translate the impact of telemedicine on the quality of care provided to our patients, families, and health-care staff.

Sources of funding

No funding support was received in this preparation of this article.

Ethical approval

Not required for this paper.

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