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Technology

Intensive care unit robotic telepresence facilitates rapid physician response to unstable patients and decreased cost in neurointensive care☆

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Abstract

Background: The timely assessment and treatment of ICU patients is important for neurosurgeons and neurointensivists. We hypothesized that the use of RTP can improve physician rapid response to unstable ICU patients.

Methods: This is a prospective study using a before-after, cohort-control design to test the effectiveness of RTP. Physicians used RTP to make rounds in the ICU in response to nursing pages. Data concerning several aspects of the RTP interaction including the latency of the response, the problem being treated, the intervention that was ordered, and the type of information gathered using the RTP were documented. The effect of RTP on ICU length of stay and cost was assessed.

Results: The use of RTP was associated with a reduction in latency of attending physician face-to-face response for routine and urgent pages compared to conventional care (RTP: 9.2 ± 9.3 minutes vs conventional: 218 ± 186 minutes). The response latencies to brain ischemia (7.8 ± 2.8 vs 152 ± 85 minutes) and elevated ICP (11 ± 14 vs 108 ± 55 minutes) were reduced ($P < .001$), as was the LOS for patients with SAH (2 days) and brain trauma (1 day). There was an increase in ICU occupancy by 11% compared with the prerobot era, and there was an ICU cost savings of $1.1 million attributable to the use of RTP.

Conclusion: The use of RTP enabled rapid face-to-face attending physician response to ICU patients and resulted in decreased ICU cost and LOS.

Keywords: Intensive care; Telemedicine; Telepresence; Brain trauma; Subarachnoid hemorrhage; Stroke; Intracerebral hemorrhage; Length of stay; Hospital cost; Robotics

1. Background

Timely assessment and treatment of ICU patients are major goals in intensive care [7]. This requirement is particularly difficult given the shortage of available intensive care physicians and surgeons [1] as well as the unavailability of ICU beds. Delays in both patient assessment and physician response can result in lost opportunities to improve patient outcome and can result in increased morbidity and length of stay [6]. These problems particularly affect neurocritical care patients, as the dichotomy between the need for rapid intervention and the shortage of highly trained experts is most acute [10]. Most neurocritical care patients have a high risk for brain ischemia, and the time window for intervention for brain ischemia is quite short. Hence, there is a great need to quickly identify and rapidly respond to brain ischemia once it occurs.

Abbreviations: EKG, electrocardiogram; GCQ, Global Care Quest; ICH, intracerebral hemorrhage; ICP, intracranial pressure; ICU, intensive care unit; LOS, length of ICU stay; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; OI, operational index; RTP, robotic telepresence; SAH, subarachnoid hemorrhage; TBI, traumatic brain injury.

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The most common response paradigm to an emergent issue in the ICU is the physician telephonic response paradigm. In this paradigm, the nurse detects a change in neurologic exam or an abnormal finding on brain monitoring, such as elevated ICP. The nurse then urgently pages the ICU physician and in turn the physician uses telephonic communication to respond to the page. Information is verbally exchanged over the phone, typically in the absence of visual information or review of the electronic monitors. The physician integrates the verbal information that is shared by the nurse and then issues an order or set of orders designed to stabilize the patient. In this paradigm, the physician may not have a face-to-face contact with the patient for many hours. This paradigm is the present standard of care and generally is delivered by physicians working in ICUs and by nonintensivists following patients in the ICU setting. However, the quality and safety of this telephonic response paradigm have heretofore not been tested and delays in definitive care after a face-to-face contact are commonplace.

The design of this pilot trial was to catalogue the unique characteristics and benefits of a new response paradigm predicated on the use of RTP. Robotic telepresence was used by attending physicians to respond to pages by the ICU nurse in an academic hospital setting. RTP is a form of telemedicine which enables a direct face-to-face rapid response by the physician, instead of the traditional telephonic paradigm. Specifically, we hypothesized that that the use of RTP decreases the latency of the attending physician's face-to-face response to unstable patients in the ICU.

2. Methods

This prospective observational study was approved by the UCLA institutional review board. The study was conducted over a 12-month period from June 2005 to June 2006. A single center and single ICU was used for this process. During the 1-year period of study, 2 physicians participated in the study using RTP. A total of 640 neurologic and neurosurgical patients were admitted to the ICU with one of the following diagnoses: TBI, SAH, ICH, ischemic stroke, or brain tumor. Table 1 outlines the patient population characteristics and diagnoses. Of note, this population was focused on neurocritical care patients including neurotrauma patients. Prospective information on the overall length of stay per patient, and mortality rate were collected for each patient. These data were compared with that from a cohort of 578 matched patients from a prerobot period during the 2003-2004 fiscal year.

Table 1
The demographic information for the 2 patient cohorts are shown

Category	2003-2004 Prerobot	2005-2006 Robot
Diagnosis		
SAH	129	139
ICH	80	80
Stroke	82	83
Seizures	29	37
Tumors	125	132
TBI	133	169
Total	578	640
Age (mean)	54 ± 18	53 ± 19
% Mortality (mean)	10% ± 5%	11% ± 7%

The prerobot cohort is represented in the 2003-2004 data.

Implementation of a prospective nighttime set of rounds using remote RTP was carried out. Using RTP, the ICU attending, while sitting in his/her home office, would round on each patient for at least 5 minutes and discuss the patient with the bedside nurse. These rounds occurred during the hours 8 PM to midnight on weekdays and at 6 PM on weekends. During these rounds, trends in physiologic variables such as ICP and treatment goals, such as glycemic control, were reviewed. During these encounters, the attending would ask if there were any concerns or any potentially unstable patients. In addition, walk-up questions from nurses were encouraged during this period. To examine a patient, the physician would drive the robot up to the bedside and speak loudly to the patient, requesting the patient to perform selected components of the neurologic exam. For unresponsive patients, the bedside nurse would shine a light into the pupils one at a time and then provide noxious stimulation to the patient to evaluate motor response. The physician would watch this exam and coach the nurse to adjust the exam to elicit the best information. A similar interactive exam was done in response to a physician page.

A systematic physician paging protocol was established as routine care before the inception of the trial. The protocol begins with the ICU nurse practitioner or bedside nurse placing a text message page to the attending physician for emergency or triage questions concerning patient care. The decision of when to page the attending physician was left to the bedside nurse, but general criteria for paging were defined: unstable patients with elevated ICP or alteration of ICP waveform, suspected brain ischemia, deterioration in Glasgow Coma Score, refractory hypotension or hypoxemia, or bed triage/bed control issues requiring supervisory decisions. The response goals were prospectively outlined so that routine pages would be answered within 15 minutes of the page.

2.1. Physician response categorization

Each RTP episode was captured using a structured questionnaire completed by the attending physician. The questionnaire was designed to catalogue several descriptive aspects of the telepresence interaction including these main categories: (1) response latency to a physician page, (2) the principal critical care diagnosis, (3) the nature of the new clinical problem, (4) the type of new data evaluated by the physician via RTP, (5) the principal intervention made by the physician, (6) the customary delay in face-to-face response if RTP was not available. The decrease in latency of face-to-face response time by an attending physician to an important clinical event was evaluated by comparing the customary delay to the actual delay in a face-to-face visit between the attending physician and the patient. The method of notification was determined to be a page or a walk-up notification during an ongoing telepresence interaction. In the former, the nurse pages the attending and the attending responds via telepresence; in the latter, the nurse walks up to the robot while an RTP session is already underway. With each item, a predefined set of selections were devised to be sufficiently broad as to capture the essence of the physician's response and to enable comparison of categories of response between patient encounters. Each new clinical problem per patient was captured, with up to 3 new clinical problems per patient per RTP session could be selected using the questionnaire.

2.2. Robotic system

The computer control station for the telepresence robot (InTouch Health, Santa Barbara, Calif) is integrated with an informatics system called Global Care Quest (GCQ, Aliso Viejo, Calif). Global Care Quest is a proprietary system that serves to automatically acquire information from a variety of hospital-based electronic data systems, including radiology, laboratories, and medical records, and display this information on a user-friendly dashboard display. This dashboard display is simultaneously accessed and displayed adjacent to the live telepresence audio-visual display from the ICU that is captured in real time by the robot. The robot display is on the left panel and the GCQ display is on the right panel (Fig. 1). The physician can select from a variety of information sources on GCQ to facilitate the telepresence encounter. The telepresence robot is a commercially available device (InTouch Health) that has a 2-way digital audio-video camera that permits observation and face-to-face interaction between doctors and nurses. The Telepresence Robot is mobile and is controlled remotely by the doctor using a computer workstation to move in the ICU and is able to have real-time communication. The robot has an anthropomorphic design consisting of a head (flat screen TV) and a cylindrical body mounted on a mobile frame that is able to move around the ICU from bedside to bedside, and move the head to face people in the ICU, such as nurses and other doctors. The dimensions of the robot are 5.7 in tall with a base of 20 in wide.

3. Results

3.1. Intensive care unit demographics and performance

There were 640 categorical admissions to the ICU during the study period. There was a mean of 2 RTP sessions per day. The nighttime rounding session averaged 52 ± 8 minutes and the response-to-page sessions averaged 9.2 ± 9.3 minutes. The main diagnoses, age, sex ratio, mean ICU length of stay, and other parameters are outlined in Table 1. Compared with the number of admissions for 2003 to 2004, there was an 11% increase in the number of ICU admissions in 2005 to 2006 (578 [2003-2004] vs 640 [2005-2006]). During the active study period, the overall mean ICU length of stay was reduced by 0.5 days compared with 2003 to 2004. In comparison of ICU LOS during the prerobot era, 2003 to 2004, with the robot era (2005-2006), a reduction in LOS was demonstrated for patients with SAH (11 vs 9 days), TBI (8 vs 7 days), and ICH (11 vs 10.6 days), but unchanged

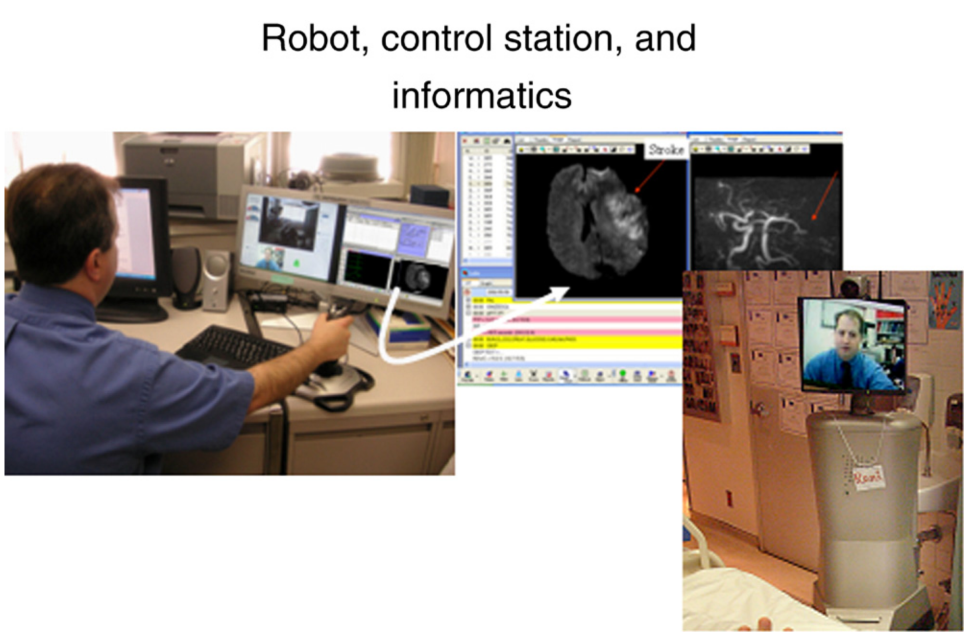

Fig. 1. The physician is shown at the control station, operating the joystick and interacting with the ICU. The insert shows the ICIS GCQ dashboard which in this example displays the diffusion-weighted MRI and MRA showing the ischemic stroke. The lower right corner shows the robot at the bedside, and the face of the physician is visible to the patient.

Table 2
A: The ICU LOS and cost comparison by the categories of disease seen in the ICU, namely, SAH, TBI, tumors, stroke, and ICH. B: The percentage of patients occupying the ICU for <7 days in each category is shown

	2003-2004	2005-2006
A. ICU LOS (in days)		
Entire group	8 ± 8.3	7.5 ± 8.8
SAH	11 ± 9.3	9 ± 9
TBI	8 ± 7.8	7 ± 9
Stroke	6.2 ± 4.4	6.4 ± 7.3
Tumor	4.6 ± 5.3	5.2 ± 8
ICH	11 ± 11	10.6 ± 9.6
B. Percentage of ICU LOS <7 d		
SAH	46%	54%
TBI	63%	68%
Stroke	71%	73%
Tumor	79%	81%
ICH	52%	51%

in those patients with stroke and tumor (Table 2). The reduction in length of stay was mirrored by a reduction in the proportion of patients who spent 1 week or less in the ICU, such that, on average, patients stayed in the ICU for a shorter period. For patients with SAH and TBI, there were an 8% and a 5% increase, respectively, in the proportions of patients staying for 1 week or less.

3.2. Reasons for paging the attending physician

The principal reasons for paging the physician are outlined in Table 3. Brain ischemia followed by respiratory distress were the 2 most frequent individual categories for paging the physician. However, in the aggregate, neurologic problems accounted for 50.6% of all pages to the attending. Through the use of nighttime telepresence rounding, 54% of pages occurred owing to "walk up" inquiries to the attending by the bedside nurse while the attending was telepresent. These walk-up inquiries resulted in a median of 2 new notifications for each nighttime telepresence session.

3.3. Data acquired via telepresence

The main types of critical data acquired from the telemedicine interaction were judged by the attending physician to be important in the decision pathway. The distribution of this critical data is as follows: 67% visual and 33% verbal information (Fig. 2). Of the visual information, the breakdown was as follows: Physical examination (40.6%), physiologic monitor graphics (11.5%), printed information from the medical record (5.8%), body language of the nurse (5.7%), information about a tube or catheter (3.8%). The ability of the robot to accurately focus on the visual information to obtain the critical diagnostic information was judged by 2 measures, the validity index and the OI. The validity index was defined as the percentage time of adequate information/number of visual event and was found to be 100%. The OI was defined as the percentage time taken to focus on the visual target/time of the overall patient encounter. The OI averaged 0.05 ± 0.06. For example, it took 15 seconds to focus in and interpret an EKG monitor in a 5-minute overall encounter with a patient (OI = 15 seconds/300 seconds = 0.05). The reliability of the RTP system was quite good in the present study. The system worked and was routinely available at all times of day. Specific Internet availability problems caused by downtimes by the available Internet service provider and interruption of wireless connection at the hospital side of the system were the 2 most frequent causes of service disruption. However, these problems accounted for less than 1% downtime for all available times of need.

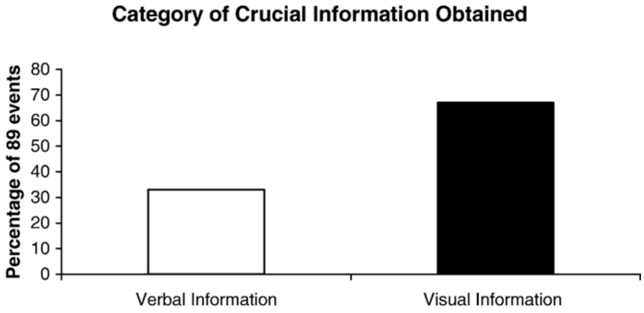

Fig. 2. The percentage of RTP events in which visual information was found to be the critical piece of information (solid) accounted for more than two thirds of all events, whereas verbal information (open) was critical in about one third of event.

Table 3
The reasons for the nurse to page the attending physician shown as percentage of total pages

Reasons for paging	% of total
Brain ischemia	20
Respiratory/hypoxemia	19
ICP	16
ICU discharge	11
Seizure	9
ICU Bundle issue	9
Delirium	5.6
Hypertension/arrhythmia	4.4
Renal insufficiency	3
Hypotension	3
Total	100

Table 4
The intervention orders by the attending physician during the RTP encounter shown as a percentage of all such interventions

Interventions by RTP	% of total
Brain ischemia/vasopressor	22
Respiratory/ventilator	20
ICU Bundle/RN mentoring	12.3
Seizure	10
ICP Control	7
ICU Bed control	7
Urgent antibiotics	7
Sedation	7
Cardiovascular disease/hypertension	4.4
Diuresis	3.3
Total	100

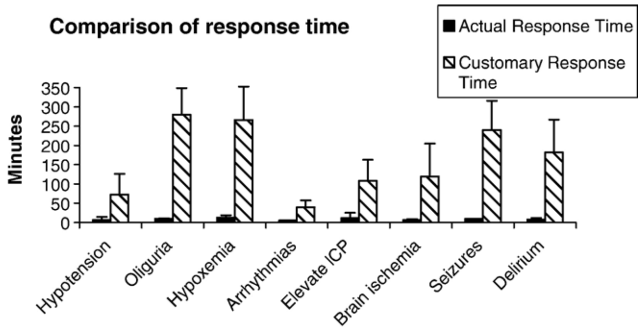

Fig. 3. The comparison between actual (solid) vs customary (striped) face-to-face response latency for specific categories of clinical problems. Univariate analysis demonstrated statistically significant reduction in the response latency for each category and for the composite overall ($P < .001$).

3.4. Types of interventions ordered

The interventions ordered by the attending were categorized by the reasons for paging the physician and the type of intervention ordered. Table 3 outlines the main reasons for paging the attending physician. The most common reason was brain ischemia followed by hypoxemia. Table 4 outlines the main interventions made using RTP. The main type of intervention was hemodynamic resuscitation using fluids and/or vasopressors, followed by treatment of respiratory failure. Given the high incidence of brain ischemia, the treatment of vasopressors and/or fluids was given primarily to treat presumptive brain ischemia. Of note, mentoring interactions with nurses and other bedside professionals to remind them of the ICU bundles accounted for more than 12% of the interventions.

3.5. Decrease in the latency of response time

The decrease in latency of face-to-face response time by an attending physician to an important clinical event was evaluated for a host of conditions, including hypotension, hypoxemia or respiratory failure, suspected brain ischemia, elevated ICP, and seizures (Fig. 3). Overall, there was a marked reduction in the attending physician response latency using RTP. Of note, the actual mean response time was statistically shorter for patients with brain ischemia (7.8 ± 2.8 vs 152 ± 85 minutes) and elevated ICP (11 ± 14 vs 108 ± 55 minutes) ($P < .001$). Univariate analysis demonstrated statistically significant reduction in the response latency for each category and for the composite overall ($P < .001$).

3.6. A case example

A patient with suspected brain ischemia caused by an ischemic stroke was triaged, evaluated, and treatment begun using RTP after the ICU attending was paged by the charge nurse. The ICU attending responded within 5 minutes of the page and examined the patient. The examination demonstrated that he had aphasia and right hemiparesis. The ICU attending was able to document the clinical exam and evaluate the MRI and MRA, which demonstrated the left middle cerebral artery stroke. The patient's blood pressure was initially 110/66 mm Hg, the EKG demonstrated normal sinus rhythm of 60 with no evidence of ST-segment abnormality, and the patient appeared to be mildly dehydrated. The ICU attending then ordered a 1-L fluid bolus of normal saline and continuous intravenous norepinephrine to induce hypertension for a goal systolic blood pressure of 160 to 180 mm Hg. The ICU attending reexamined the patient once every 1 hour for the next 4 hours using RTP and noted a gradual clinical improvement in language function over that 4-hour period without any evidence of cardiac strain on EKG. Fig. 1 demonstrates the remote physician evaluating the patient and reviewing the brain imaging to direct treatment.

3.7. Reduction in ICU cost

Based upon the reduction in the ICU LOS of the primary diagnoses outlined in Table 2, a calculation of the costs reduction was performed. The average cost of a day in the ICU was $1655 per day for these diagnoses. Based on the mean reduction in the LOS for each diagnosis, a cost reduction calculated for the population was made for each diagnosis using this formula: (the mean number of ICU days saved) × (the number of patients with that diagnosis per year) × (cost per day for the particular diagnosis). The total cost saved was the summation of all patients and these data are presented in Table 5. In comparison to the 2003 to 2004 year, there was a net ICU cost reduction in 2005 to 2006 of $1.1 million. This reduction in cost was attributed to the decreased length of stay of patients with SAH and TBI.

Table 5
The comparison of the change in ICU cost between the 2 study periods, 2003-2004 and 2005-2006

Cost savings based on ICU LOS using robot (in dollars hospital cost comparing 2003-2004 to 2005-2006)				
Diagnosis	Cost savings/diagnosis	Days saved/diagnosis	No. of patients/diagnosis	Cost savings/year
SAH	3310	2	139	920 180
TBI	1655	1	169	279 695
Stroke	−331	−0.2	83	−5495
Tumor	−993	−0.6	132	−78 646
ICH	662	0.4	80	21 184
Total				1 136 918

The cost savings are derived from the average cost of 1 day in the ICU, which averaged $1655 for the patients in the study. The negative numbers indicate the additional cost for those diagnoses based on an increased LOS.

4. Discussion

The principal results of this prospective study on the use of RTP in the neurointensive care unit are as follows: (1) RTP is feasible and reliable in the ICU. (2) Critical visual information is gathered and used in the diagnostic and decision-making process when using RTP. (3) The use of RTP results in a marked reduction in the attending face-to-face response time for critical patient care problems in an academic hospital. (4) Robotic telepresence is used most often to address acute problems of brain ischemia. (5) The use of RTP is associated with a reduction in the mean LOS in patients with SAH and brain trauma. (6) The reduction in ICU LOS results in an increased capacity for patients and a substantial reduction in ICU cost in excess of $1.1 million.

RTP is a relatively new information technology in healthcare that makes use of real-time, face-to-face interactions between physicians, nurses, and patients [9]. RTP is a remotely controlled robot which projects the physician's real-time audio and video image to the patient, nurse, and other healthcare team members in a seamless experience. The "audience" is able to interact with the remote physician in real-time and vice versa. The entire experience results in a virtual presence experience with a high degree of satisfaction from both the physician and the "audience." The integration of GCQ ICIS (GCQ) into the RTP workstation creates a clinically empowered network which enables the physician to interact with the patient and to examine all clinically relevant data simultaneously. RTP is highly reliable, mobile, and demonstrated a high success rate, without failures that have recently been documented in fixed, stationary telemedicine systems [11]. The types of information that was presented using GCQ ICIS included routine laboratory data, trends of point-of-care testing, radiologic imaging, and electronic reports. The combined GCQ ICIS and RTP system constitutes a novel information delivery and communication platform. Our group was among the first to use the RTP in the ICU to assess and treat unstable patients. This paper represents the first analysis of such a system for neurosurgical ICU patients.

We demonstrated that visual information acquired via RTP was critical to the interaction. The visual information gathered ranged from physical examination findings, physiologic monitoring waveforms to radiographic images. This finding underscores the role that a visual impression of the patient plays in analysis of a clinical situation and outlines the importance of visual data review in an ICU. The visual data were one of several types, located in disparate parts of the ICU (ie, patient bed, the bedside monitors, the nursing station) and hence provides insight into the value of mobility of the robot to move around the ICU. The data suggest that a single anchor point for a telecommunication system might limit the ability to gather visual information and hence be inadequate in the majority of telemedicine interactions in our center.

The reliance on visual information also reveals the potential shortcoming of routine telephonic response to a page. One must acknowledge that the majority of physician responses to a page involve telephonic communication without direct visualization or a delay in visualization of the patient. The delay in visualization results from the inability of a physician to be in the ICU at all times, and the reality of travel time from home to the ICU, despite the leapfrog recommendations [5]. A more insidious reason for the delay is the misdiagnosis that results from a deficit in visual data that is required to make the correct diagnosis. The latter problem has been incompletely studied.

The primary clinical endpoint of this study was that RPT results in rapid face-to-face response by the attending physician to the ICU patient. The data demonstrate that a dramatic reduction in the response latency occurred. This was most profound for respiratory and neurologic instability. The reduction in response time to elevated ICP and brain ischemia is clinically meaningful as the time window to intervention is quite short. For example, customary time for an attending physician to visually see a patient with elevated ICP averaged 108 minutes. With the use of RTP, the mean time to a face-to-face contact was about 11 minutes. This reduction in latency is substantial and clinically meaningful as it is well recognized that the duration of untreated, elevated ICP is a major determinant factor for morbidity and mortality after TBI. Indeed, it is particularly noteworthy that there was a reduction in latency for those paroxysmal events that could cause irreversible brain damage, namely, brain ischemia, elevated ICP, seizures, hypotension, and hypoxemia. This reduction was mirrored by the reduction in the length of stay in those patients who are most at risk for brain ischemia, namely, those with SAH, stroke, and brain trauma. Our findings are similar to the initial experience using telemedicine to treat ischemic stroke [3]. In the latter study, tissue plasminogen activator was given more rapidly when a telemedicine system was used by stroke neurologists. Unfortunately, the current study was not prospectively designed to determine whether this rapid response time resulted in improved outcomes for these patients, and, realistically, such a study would require large numbers of patients. However, this finding outlines the feasibility for attending level supervision of patients and provides a basis for multicenter outcome-based studies.

It is noteworthy that we were able to use the robot to discuss on a face-to-face basis many aspects of care with the bedside ICU nurse. This is reflected in Table 4, in which we note that the robot was used for mentoring nurses, discussing admission and discharge issues with the charge nurse, and discussing ICU bundles (ie, treatment protocols) to facilitate compliance with standard protocols. The nurses were very receptive to this face-to-face interaction and reported a high level of satisfaction with the robotic encounter. The role of RTP in facilitating compliance with treatment protocols and critical pathways was potentially a significant factor affecting our length of stay outcomes, as would be expected from prior studies [4].

An unanticipated finding of the present study was that there was a reduction in the length of stay across all patients, especially for those who are at risk for brain ischemia and secondary insults. Patients with SAH, brain trauma, and ICH had a reduction in length of stay and an increase in the percentage of patients spending a short time in the ICU (<7 days). This reduction in LOS led to an overall cost savings for the ICU during the year 2005 to 2006 in comparison with 2003 to 2004, while at the same time increasing the capacity of the ICU by 11%. The ability of RTP used in conjunction with an ICU attending response protocol to reduce cost and increase occupancy resulted in substantial financial savings, exceeding $1.1 million. To be sure, this analysis is conservative, because we did not factor in the additional physician and hospital opportunity earnings that resulted from more efficient use of the ICU beds. The latter is particularly interesting given the perennial lack of postoperative beds in our center. We hesitantly speculate that the quicker response times to brain ischemia and elevated ICP, which comprised roughly 36% of the urgent pages, may have resulted in avoidance of secondary brain injury and hence earlier discharge from the ICU. Others have demonstrated that intensive care telemedicine can have a profound impact on quality and cost of care [4,8]. Our results appear to support this concept using a different telemedicine application. This improvement in ICU bed efficiency did not occur at the expense of patient outcome, as our mortality rates were similar between the 2 comparison time frames. The use of RTP enables us to meet the requirements set forth by the leapfrog initiative to have expert intensivist coverage and availability in the ICU [5] and couples this achievement with a reduction in ICU cost. Both achievements are particularly timely given the high costs of intensive care [2] and the pressure to become more cost effective and to reduce medical errors.

The limitations of this study consist of the following: (1) this study was confined to a single academic medical center. An academic medical center represents a unique hierarchical structure of physician responsibility for patient care. Hence, the bedside nurse will typically address new problems to available nurse practitioner or house staff, and many clinical problems are routinely handled without the immediate input of the attending physician. Hence, our report is over-representative of emergency events that were of a profound clinical burden. Hence, it is unclear to what extent the findings are generalizable to community medical centers. (2) The study was not designed to determine whether neurologic outcome was improved in the most frequent patients in the ICU, namely, those with SAH and TBI. (3) The study is not randomized and hence suffers from the lack of concomitant controls. In defense of this criticism, this model was used in other telemedicine studies (Breslow) and the periods for comparison were contemporaneous.

5. Conclusion

The use of RTP in a neuroscience ICU results in many benefits including (1) rapid assessment of unstable patients by the attending physician, (2) reduction in the length of stay for patients with cerebrovascular and traumatic neurosurgical illness, (3) a reduction in hospital cost, (4) an improved efficiency and net bed capacity for the ICU. These benefits are cost-effective and hold the promise that RTP can be used in a variety of ICUs to enhance patient care and provide more efficient use of our limited human and structural resources in neurocritical care.

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