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ORIGINAL ARTICLE

The effect of robotic telerounding in the surgical intensive care units impact on medical education

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Abstract Robotic telerounding is effective from the standpoint of patients' satisfaction and patients' care in teaching and community hospitals. However, the impact of robotic telerounding by the intensivist rounding remotely in the surgical intensive care unit (SICU), on patients' outcome and on the education of medical students physician assistants and surgical residents, as well as on nurses' satisfaction has not been studied. Prospective evaluation of robotic telerounding (RT) using a Likert Scale measuring tool to assess whether it can replace conventional rounding (CR) from the standpoint of patients' care and outcome, nursing satisfaction, and educational effectiveness. RT did not have a negative impact on patients' outcome during the study interval: mortality 5/42 (12 %) versus 6/37 (16 %), RT versus CR, respectively, $p = 0.747$. The intensivists rounding in the SICU were satisfied with their ability to deliver the same patients' care remotely (Likert score 4.4 ± 0.2). The educational experience of medical students, physician assistants, and surgical residents was not affected by RT (average Likert score 4.5 ± 0.2, 3.9 ± 0.4, and 4.4 ± 0.4 for surgical residents, medical students and PAs, respectively, $p > 0.05$). However, as shown by a Likert score of 3.5 ± 1.0, RT did not meet nurses' expectations from several standpoints. Intensivists regard robotic telerounding as an effective alternative to conventional rounding from the standpoint of patients' care and teaching. Medical students, physician assistants (PA's), and surgical residents do not believe that RT compromises their education. Despite similar patients' outcome, nurses have a less favorable opinion of RT; they believe that the physical presence of the intensivist is favorable at all times.

Keywords Robot · Telerounding · SICU · Medical education · Outcome

Introduction

A recent study comparing conventional bedside rounding with robotic telerounding (RT) has shown that RT improves patients' satisfaction with postoperative care from the standpoint of physician availability [1, 2]. Additional studies have confirmed the clinical effectiveness, and cost savings associated with the use of RT in community and university hospitals [2–4]. Furthermore, RT has been shown to decrease the intensive care unit (ICU) length of stay and the overall cost in a neurointensive care unit [5]. However, all studies addressing the potential use of RT either to replace conventional bedside rounding or to enhance care in the ICU settings by extending the off-site availability of the intensivist have not addressed the impact of RT on nurses, medical students, residents, physician assistants, and in the case of the ICU settings on the intensivists themselves, as well as on patients' outcome. It is within this context that we designed this prospective study.

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Study design and methods

This study was designed as a prospective longitudinal study. It included an experimental period during which RT was undertaken in the surgical intensive care unit (SICU) and a control interval when conventional rounding with the same personnel was undertaken. The SICU is an 8-bed closed model SICU in a large tertiary care teaching hospital serving a diverse group of critically ill patients, including general, vascular, urologic, and oncologic patients. All patients are managed exclusively by the surgical/medical intensivists from the Division of Trauma/Surgical Critical Care of the Long Island Jewish Medical Center. During both study intervals, the care to the SICU patients was rendered based on a protocol-driven approach. The same three PGY-2 surgical residents assigned to the SICU provided 24-h coverage on a rotating basis during the experimental and control study intervals. Consultations were requested only by the surgical/medical intensivist when deemed necessary. Communication with families, including discussion of end-of-life issues and withdrawal of life-sustaining measures, was undertaken daily by the full-time surgical/medical intensivists using RT during the experimental period. The coverage provided by the surgical/medical intensivists during CR included morning rounds and afternoon rounds. Night coverage was done robotically during the experimental interval by the same attending intensivist covering during daytime; however, night coverage during the CR interval involved coverage by per diem intensivists on a rotating basis. A review by the hospital's Institutional Review Board (IRB) determined that their approval was not required since there was no change in patient care.

Admission to the SICU was permitted only after consultation with the intensivist on call for the day. All discharges from the SICU were initiated by the intensivist and coordinated with the floor admitting team. The surgical/medical intensivist was required to be *physically* in the SICU for a minimum of 6 h each day during CR; however, during RT the attending could round as frequently as needed using the robot after having conducted his routine morning RT. The SICU weekend coverage remained the same during both study intervals. The robot was driven to each patient bedside, in the same way as walking into the patient room. All team members except the surgical intensivist were physically present at the bedside of the patient during RT.

Before commencing RT, all intensivists underwent a supervised training period of 1 week with an In-Touch Health Corporation technician to become proficient in the use of the RP6 robot. Upon satisfactory completion of training, the intensivists participating in the study were allowed to undertake RT. The study participants included four intensivists (INT), three PGY-2 surgical residents (SR), four physician assistants (PA), four medical students (MS), and 13 nurses (RN). RT was evaluated for a total of 20 days. Weekends were excluded since due to the 80-h work week regulations and nursing shifts study participants were not consistently available on weekends. Each attending made RT for five consecutive days each week. We used four 10-item questionnaires individualized to specific study participant groups to evaluate participants' ratings of their ability to communicate effectively, ability to deliver patients' care comparable to that delivered during conventional rounding, andoverall educational experience (Fig. 1). Every day each study participant was required to fill the 10-item questionnaire specific for his/her group. Each item was ranked using a Likert scale, where $1 =$ strongly disagree, $3 =$ uncertain, and $5 =$ strongly agree with the given question. The experimental study interval was compared to a subsequent 4-week control interval when the same personnel were present (May 1st 2007 to May 31st 2007). In addition to the daily questionnaires, data acquired during the experimental and control intervals included acuity of disease by Apache II scores, percentage of patients on ventilatory support, SICU length of stay, and predicted and actual mortality.

Device

The telerounding robot "RP6" (InTouch Health, Santa Barbara, California) is a 60-inch tall wheel-driven device consisting of the motor base unit, a central processing unit, a high-definition digital camera, a flat-screen monitor, and a microphone. Data to and from the robot is transferred over a high-speed wireless network. The physician connects remotely to the robot via a laptop computer equipped with a high-definition camera, a flat-screen monitor, a microphone, and a joystick controller. The physician rounding remotely can split the screen of the robot to embed teaching slides, or to draw as needed for teaching purposes. The robot can be driven remotely throughout the hospital. During the experimental interval, before undertaking RT, patients and their family members were shown the robot and informed that they would interact with the intensivist through the robot's flat-screen monitor. Additionally, they were shown during a demonstration that they would be able to communicate with the rounding intensivist via the robot.

Statistical analysis

Data are presented as mean $\pm$ SD. Means within and among groups were compared with ANOVA and difference were localized with Neuman–Keuls test. When indicated, Chi square was used to evaluate groups' differences

Fig. 1 Intensivist's Questionnaire

1. Were you able to communicate effectively with the patient and all team members?
2. Do you feel that you were as effective in rounding in the SICU as you are when physically present?
3. Were you able to interact effectively with the nurses taking care of the patients?
4. Were you able to evaluate effectively spreadsheets, ventilator settings, hemodynamic variables, and x-rays to draw therapeutic conclusions in a manner similar to when you are physically present?
5. Was your interaction with residents, physician assistants, and medical students as effective as it is during conventional rounding?
6. Do you believe that the residents responded to you in a manner comparable to that observed when you are physically present?
7. Were you able to teach all team members with the same effectiveness of conventional rounds?
8. How comfortable are you in supporting remote rounding as an alternative to conventional rounding?
9. Do you feel that patients' needs were met as during conventional rounds?
10. Do you feel that your overall effectiveness was similar to that displayed during conventional rounds?

in categorical variables. Pearson's correlation test was used to establish correlation within and between groups. All tests were two-sided. Statistical significance was accepted to correspond to a p value less than 0.05. For the standpoint of statistical analysis, the 13 nurses were divided into three groups based on nursing shifts: 1–4, 5–6, and 7–13.

Results

As shown in Table 1, the SICU patients' characteristics did not differ between the experimental and control intervals. The acuity of disease and percentage of patients requiring ventilator support was not statistically different between the study interval and the subsequent control interval. RT did not have a negative impact on SICU length of stay, and patients' outcome in the SICU during the experimental period when compared to the control interval. Shown in Table 2 are the data for all study participants over the 4-week interval. One of the three surgical residents participating in the study was uncertain about the overall value of RT by the end of the first week of the study. However, by the end of the fourth week, all three residents participating in the study were satisfied with RT being as effective as conventional rounding with respect to all questions on their questionnaire. Residents tended to become more comfortable with RT over time.

Table 1 Patients' characteristics during the study intervals

Variable	Robotic telerounding	Conventional rounding	p value
Number of patients	42	37	
Number of patients on ventilator	25/42 (59 %)	18/37 (48 %)	0.379
Average LOS	5 ± 2	6 ± 3	0.568
Apache II score	18 ± 3	19 ± 5	0.279
Predicted mortality	26 ± 3	30 ± 5	0.278
Actual mortality	5/42 (12 %)	6/37 (16 %)	0.747
SMR	0.4	0.5	NA

LOS Length of stay, *SMR* standardized mortality ratio

Three of the four PAs believed that RT was as effective as conventional rounding. However, one of the four PAs felt consistently that RT could not replace conventional rounding from most standpoints. While his satisfaction with RT improved over time, by the 4th week, he remained uncertain about the ability of RT to replace conventional rounding in the SICU. All medical students were satisfied with RT. There was a statistically significant difference among the nurses involved in the study with respect to their acceptance of RT; four nurses believed that RT could not replace conventional rounding, two nurses were uncertain and the remaining seven nurses strongly agreed with RT being as effective as conventional rounding.

In contrast to the nurses' response to the questionnaire, all four intensivists agreed with respect to the effectiveness of RT from all standpoints of performance, including their ability to deliver appropriate medical care. A comparison among all groups showed that, while not reaching statistical significance, nurses were less prone to accept RT as an

Table 2 Likert scores over time in the study groups

Participant	Week 1	Week 2	Week 3	Week 4	Aggregate	*p*
Residents	4.1 ± 0.9	4.4 ± 0.4	4.3 ± 0.6	4.9 ± 0.1	4.4 ± 0.4	0.29
MS	3.9 ± 0.6	4.7 ± 0.2	4.8 ± 0.4	4.8 ± 0.4*	4.5 ± 0.2	0.03
PAs	3.6 ± 0.7	4.1 ± 0.8	3.9 ± 0.6	4.0 ± 0.2	3.9 ± 0.4	0.69
RNs	3.5 ± 0.8	3.5 ± 1.1	3.5 ± 0.8	3.5 ± 0.8	3.5 ± 0.9#	1
Attendings	4.6 ± 0.6	4.4 ± 0.5	4.3 ± 0.4	4.3 ± 0.4	4.4 ± 0.2	0.79

* $p < 0.05$ versus week 1

# $p < 0.05$ versus residents, medical students, and attending

effective replacement of conventional rounding. Shown in Table 2 is the effect of time on the degree of acceptance of RT as an effective alternative to conventional rounding among all groups of study participants. There was an improved acceptance of RT over time in the residents, medical students, and physician assistants' groups. There was no change in the level of acceptance of RT in the attendings and nurses' groups.

Discussion

Telemedicine is the combined use of telecommunications and computer technologies to improve the efficiency and effectiveness of health care services by liberating caregivers and patients from traditional constraints of time and place [6–9]. One of the best publicized telemedicine models is the eICU, promoted by Breslow and colleagues [10, 11]. The eICU concept is centered on the paradigm that a centralized workstation of intensivists can effectively supervise multiple patients in a variety of ICUs via high-speed internet connections. This model uses a combination of videoconferencing technology, electronic medical record systems, and real-time remote monitoring of patient monitors, which empower off-site intensivists and/or critical care nurses to direct patient care. The details of this model have been published [12]. To provide continuity of care by the same intensivist assigned to the ICU, we have elected an alternative telemedicine approach, called robotic telerounding (RT) that uses a mobile robot. It is unique because nurses, patients, and families can interact with the robot as if it is a person [13].

Most studies concerning RT have addressed questions surrounding patients' safety and satisfaction, as well as the physician's ability during RT to have access to all pertinent patients' information, including laboratory, radiologic imaging, and vital signs data necessary for patients' care. Our study was designed to address the issues of RT with respect to the typical interactions that occur daily in a teaching SICU. These interactions involve nurses, respiratory therapists, pharmacists, nutritional support staff, a variety of students, and physician assistants with the intensivist who is conducting the round in the unit. The expectations of the people involved in the SICU rounds are diverse; they depend heavily on the role each person plays in the SICU. On one end, residents and medical students may be more focused on learning and, therefore, they may concentrate on the impact of RT on the ability of the rounding intensivist to be as an effective teacher as he/she is during conventional rounds. On the other end, nurses, respiratory therapists, pharmacists, nutritionists, and PAs may be focused more on the practical aspects of patients' care during rounds including having an intensivist at the bed side when needed. Therefore, their view of RT may be different from that of residents and students. Our findings indeed suggest, although to a non-statistical significant level, that RT is viewed differently from nurses and some PAs, as opposed to medical students and residents.

The acceptance by medical students and surgical residents of RT can be explained by the fact RT does not have a negative impact on learners, since it does not prevent the most important aspect affecting learning. Namely, the degree of engagement that comes with the interactivity between the learner and the educator where interactivity is defined, as being reciprocally active, allowing a two-way flow of information between the source and the user. Clearly, RT allows the degree of interactivity needed for learners to be engaged in small group discussions as it usually occurs during conventional rounds in the SICU. Additionally, the intensivist rounding remotely can use part of his screen to draw diagrams or anything he/she wished to highlight or, to immediately embed teaching presentations stored on the laptop that he/she is using for RT. This permits the educator to possibly be even more effective than when he/she conducts conventional rounds. However, one interesting observation derived from our study concerns the impact of RT on the teaching effectiveness of the intensivist. To evaluate this aspect, we compared our monthly web-based teaching evaluations (1–3 very poor to poor, 4–6 satisfactory to good, 7–9 excellent to outstanding) of the four intensivists participating in the study with the teaching-related questions in the 10-item questionnaire. From the analysis of the data pertaining to teaching, it appears that if one is a poor teacher in conventional settings, he/she becomes an even worse teacher when doing RT.

The overall comments on the robotic rounding experience were that it is very user dependent. Excellent experience depending on who is controlling the robot. It cannot replace physical rounding by the intensivist. It depends solely on connectivity.

It is clear from the results of our study that despite the fact that nurses had the ability to discuss on a face-to-face basis each patient with the intensivist rounding remotely to implement treatment protocols and specific diagnostic and therapeutic modalities, they were not convinced that RT could replace conventional rounds because it was their opinion that the physical presence of the intensivist is a necessary element of the SICU care. This is probably the result of our SICU care model where during a conventional day, the intensivist is physically present and immediately available for at least 6 h every day permitting nurses to bypass the surgical resident if they wish to do so. This finding contrasts with the results of a previous study undertaken in a neurointensive care unit showing a high level of nurses' satisfaction with robotic telerounding and a more recent study that incorporated the use of the robot within the workflow of providing daily care for critically ill patients in an SICU [5, 14]. However, in the study conducted in the neurointensive care unit, nurses confronting an emergency situation could access physicians only by paging them and in turn the physician would use the telephone to communicate and make decisions without any visual information and review of electronic monitors. Clearly, the degree of acceptance of RT and telemedicine by nurses depends heavily on whether the ICUs in which they work are staffed with on-site intensivists. It is very likely that nurses working in ICUs with on-site intensivists will continue to prefer conventional rounding, whereas nurses who work in units without on-site staffing and/or in small community hospitals will very likely embrace RT and telemedicine because it can provide timely assessment and treatment with obvious opportunities to improve patients' outcome. Overall, it appears that RT can be used instead of conventional rounding in an SICU in a teaching hospital; however, the implementation of RT requires an increased acceptance by nurses before it can replace effective conventional rounding. In our study, we did not address the use of RT to conduct multidisciplinary rounds with all team members confined to a conference room to minimize the noise and traffic typically generated by the multidisciplinary team and to minimize the chance of transmission of nosocomial diseases.

One limitation of this study is the lack of inclusion of patients and family member satisfaction as a study endpoint. This small study interviewed a finite number of practitioners that could be biased in favor of RT. A larger study incorporating more critical care units and the practitioners is needed to validate these results.

Conclusions

Intensivists regard robotic telerounding as an effective alternative to conventional rounding from the standpoints of education, nursing interaction, and patients' care. Surgical residents have an overall positive impression of robotic telerounding and do not believe that it compromises their education. Physician assistants have a similar view with respect to robotic telerounding. Medical students do not believe that robotic telerounding compromises their education and their ability to interact with the intensivist. Nurses working on an in closed model SICU have a different view of robotic rounding: they are uncertain about the ability of robotic rounding to be as effective as conventional rounding.

The limitations of this study include the fact that although we included staff satisfaction, we did not include patient satisfaction as a study endpoint. Furthermore, this was a small study using a finite group of practitioners. A larger study incorporating more critical care units and the practitioners can potentially lead to different results. What worked in our SICU may not work in other ICUs.

Conflict of interest Corrado P Marini, MD, has no conflicts of interest to disclose. Garry Ritter PA has no conflicts of interest to disclose. Cordelia Sharma, MD, has no conflicts of interest to disclose. John McNelis, MD, has no conflicts of interest to disclose. Mr. Michael Goldberg has no conflicts of interest to disclose. Rafael Barrera, MD, has no conflicts of interest to disclose.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

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