Original Research

Remote Presence Robotic Technology Reduces Need for Pediatric Interfacility Transportation from an Isolated Northern Community

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Abstract

Background: *Providing acutely ill children in isolated communities access to specialized care is challenging. This study aimed to evaluate remote presence robotic technology (RPRT) for enhancing pediatric remote assessments, expediting initiation of treatment, refining triaging, and reducing the need for transport.*

Methods: *We conducted a pilot prospective observational study at a primary/urgent care clinic in an isolated northern community. Participants ($n = 38$) were acutely ill children <17 years presenting to the clinic, whom local healthcare professionals had considered for interfacility transportation (IFT). Participants were assessed and managed by a tertiary center pediatric intensivist through a remote presence robot. The intensivist triaged participants to either remain at the clinic or be transported to regional/tertiary care. Controls from a pre-existing local transport database were matched using propensity scoring. The primary outcome was the number of IFTs among participants versus controls.*

Results: *Fourteen of 38 (37%) participants required transport, whereas all controls were transported ($p < 0.0001$). Six of 14 (43%) transported participants were triaged to a nearby regional hospital, while no controls were regionalized ($p = 0.0001$). All participants who remained at the clinic stayed <24 h, and were matched to controls who stayed 4.9 days in tertiary care ($p < 0.001$). There was no statistically significant difference in hospital length of stay between transported participants and controls (6.0 vs. 5.7 days).*

Conclusions: *RPRT reduced the need for specialized pediatric IFT, while enabling regionalization when appropriate. This study may have implications for the broader implementation of RPRT, while reducing costs to the healthcare system.*

Keywords: *critical illness, pediatrics, telemedicine, transportation of patients, triage*

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Introduction

Specialized pediatric transport is the standard of care for North American children requiring interfacility transportation (IFT).[1,2] Pediatric intensivists based in tertiary care centers provide medical control for specialized teams transporting critically ill children, after providing initial telephone advice to local care providers. Critically ill children have improved outcomes when cared for by pediatric specialists,[3,4] and experience lower mortality and fewer unplanned events when transported by specialized teams.[5] Currently, a paradigm shift from the "scoop and run" method of urgent transfer to tertiary care without intervention is being supplanted by a model that favors provision of early goal-directed therapies at the referring center and during transport to improve outcomes and survival.[6–10]

Providing specialized pediatric transportation to rural areas is particularly challenging. In Saskatchewan, a Canadian province of 1.1 million people, 36% of children live in communities of <1,000 people.[11] As many of these remote centers lack the expertise and resources needed to adequately triage and manage acutely ill children, there is often significant unease in initiating therapies, declaring disposition, and waiting for stabilization before transport.[12] Thus, a solution was needed that enabled early intervention and refined transport triaging. To meet these challenges, the use of remote presence robotic technology (RPRT) was investigated in this study. RPRT is a mobile form of telemedicine that creates the sense that a distant clinician is at the patient's side, while enabling clinical services to be provided remotely in real time.[13,14] Previous studies have demonstrated a decreased need for transfer of rural adult patients to a tertiary intensive care unit,[15] and reduced medical air transports out of a Canadian arctic village.[16] In pediatrics, telemedicine allowed successful triaging and treatment of pediatric disaster victims,[17] and has been shown to be reliable for the evaluation of critically ill children, aide in determination of disposition, and enhance pediatric transport effectiveness.[18–20] It has been associated with a reduction in pediatric transfers from remote communities[21] and increased regionalization to nontertiary centers.[22] However, many of these studies did not include severity of illness and follow-up data, and were retrospective in design.

Our study's objective was to prospectively assess the feasibility and safety of using RPRT at a small clinic in an isolated northern community to assess, manage, and triage acutely ill children who were being considered for specialized IFT. It was hypothesized that by facilitating prompt assessment and intervention, RPRT would reduce the need for IFT. Furthermore, initiation of management before transport may hasten clinical improvement, resulting in patients being diverted to lower-acuity regional hospitals and shortening hospital length of stay (LOS).

Methods

STUDY DESIGN

The design was a pilot prospective propensity-matched observational study. This study was approved by the University of Saskatchewan's Biomedical Research Ethics Board and has been registered with ClinicalTrials.gov (NCT02915640).

PATIENTS

Pediatric patients were prospectively enrolled as they presented to an isolated northern clinic in Saskatchewan, Canada, from November 2014 to November 2015. Participants were identified by local healthcare professionals as any child <17 years who was acutely ill and being considered for an IFT. All parents signed an informed consent. Participants were assessed, managed, and triaged by one of two pediatric intensivists affiliated with the Pediatric Intensive Care Unit at the University of Saskatchewan and Saskatoon Health Region through a remote presence robot. With input from the local clinical team and family members, the intensivist triaged patients to either remain at the clinic or be transported by the specialized pediatric transport team with a fixed-wing aircraft to either regional or tertiary care. Participants triaged to be treated at the local clinic were followed up by the intensivist using RPRT at 24 h and 14 days after initial contact to ensure management was appropriate. Participants triaged to regional or tertiary care were followed up to determine LOS. All clinical encounters were video recorded and evaluated by an independent assessor who collected data.

THE COMMUNITY

This study recruited patients from an isolated community of under 3,000 people in northeastern Saskatchewan. Health inequities in this region are striking and can be attributed to geographical remoteness, limited health services, jurisdictional issues, and adverse social determinants of health. Nurses and nurse practitioners staff the community's primary/urgent care clinic with occasional support from itinerant family physicians. The community has 24/7 on-call services and is served by two regional referral centers within 400 km by road. As only one ambulance serves the region, nonspecialized transport vehicles (personal vehicles/taxis) are often relied upon to transport acutely ill pediatric patients. Unanticipated medical events during these nonspecialized transports leave children vulnerable to negative outcomes. As nearly half of the community's population, 48%, is <17 years, the community's leadership and healthcare providers identified pediatric acute/critical care as an urgent unmet need and actively participated in the decision regarding use of RPRT.

REMOTE PRESENCE ROBOT

The RP-7i remote presence robot (InTouch Health, Inc., Santa Barbara, CA) was used in this study. It is a United States Food and Drug Administration class II medical device approved for application in acute patient care.[14,16,23,24] The RP-7i can be controlled by any Wi-Fi connected computer with the appropriate software. The robot emulates the size of an adult with a height of 165 cm (*Fig. 1*) and has a mobile flat screen monitor that displays an image of its operator.[16] Clinicians can independently undock the robot from its wall-mounted charger and drive it to the patient at ~3 km/h.[16] The RP-7i's high definition cameras, microphones, speakers, and peripheral digital devices (stethoscope, dermatoscope, and otoscope) can also be controlled by the clinician. The robot's features allow mobility of the user to have a 360° view for direct visualization, examination, and diagnosis of the patient, as well as communication with local healthcare professionals and family members. With a nurse's assistance, the RP-7i also allows real-time auscultation and facilitates mentoring in basic procedures such as intravenous access.

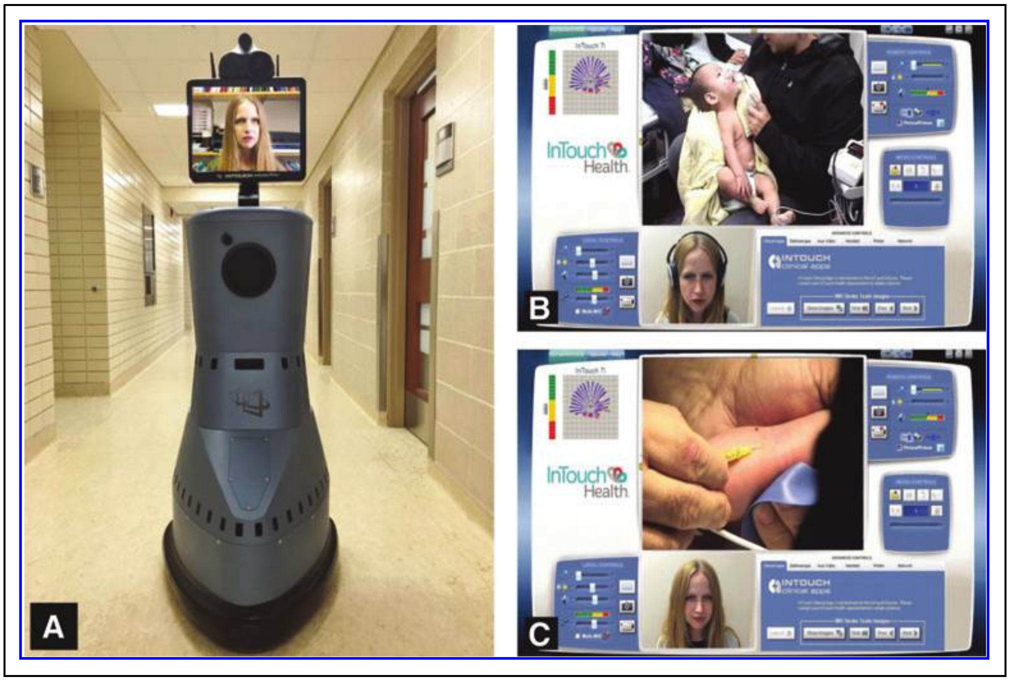

Fig. 1. The RP-7i remote presence robot. **(A)** Moving in the clinical environment, the image of the clinician controlling the robot appears on its flat screen display. **(B)** View of the control station computer showing the clinician assessing an acutely ill child. **(C)** Mentoring a local nurse in performing intravenous access. Written consent obtained from the participants.

CONTROLS AND STATISTICS

Propensity scores allow matched comparisons of interventional (RPRT) and control patients who share similar values.[25–27] Propensity score matching was used to identify controls from the 2013 to 2014 Saskatchewan Pediatric Transport Database (193 patients) for RPRT participants. All controls had been transported to a tertiary center and were not triaged with RPRT. Before estimating the propensity scores based on a set of covariates in a probit specification, the potential control groups were restricted by using key characteristics of RPRT participants (location and diagnostic category). Diagnostic categories included the following: respiratory (croup, bronchiolitis, pneumonia, and status asthmaticus), neurologic (status epilepticus and decreased level of consciousness), sepsis, and trauma. The Pediatric Canadian Triage and Acuity Scale (PedCTAS) was then applied to all participants and controls to approximate severity of illness. The PedCTAS is a validated triaging system used in Canadian emergency departments that allocates patients to different care urgency levels based on clinical presentation.[28] It has moderate interrater agreement and good correlation between triage level and severity markers.[28–31]

Propensity scores were then estimated using age, sex, PedCTAS score, and diagnostic category. Scores were generated using radius matching, an extension of the nearest neighbor matching. This approach constructs the matched control units whose propensity scores are within a tolerated distance from the propensity score of the respective intervention unit. In this study, a replacement radius of 0.005 was used,[26] which is the smallest radius frequently described in the literature.[27] Given that there can be multiple control units within the specified radius, there is more than one match for each intervention unit. In this case, all potential controls with estimated propensity scores falling within the above radius were matched with an intervention unit. The student's *t*-test and chi-squared test were used to determine statistical significance of comparative data points, with p-values <0.05 being considered significant.

OUTCOMES

The primary outcome was the number of specialized IFTs that occurred in the RPRT participants compared to the controls. For transported participants, secondary outcomes included the number of patients who were regionalized (triaged to a nearby nontertiary regional hospital) and hospital LOS compared to controls.

Results

Thirty-eight patients were recruited in the study and evaluated by RPRT (*Table 1*). Their mean age and PedCTAS score were 28 months and 2.5, respectively, and they were predominantly male (71%) with a respiratory diagnosis (71%). The control group of 193 patients was older (mean 43 months; $p=0.09$) and had fewer proportional males (57%; $p=0.1$), lower PedCTAS scores (mean 1.78; $p<0.0001$), and respiratory diagnoses (41%; $p<0.001$).

All 24 (63%) patients who were triaged to remain at the local clinic had a respiratory diagnosis (largely bronchiolitis). None remained at the local clinic beyond 24 h, and they were able to stay in their remote community. At their 24-h and 14-day reassessment, none required transport to a higher level of care. Of the remaining patients ($n=14$; 37%) who required

Table 1. Demographics and Clinical Characteristics of the Entire Sample

	TOTAL SAMPLE (*N*=231)	RPRT GROUP (*N*=38)	CONTROL GROUP (*N*=193)	*p*
Age, months, mean (SD)[a]	41.0 (51.5)	28.0 (45.1)	43.2 (52.0)	0.09
Sex, male, *n* (%)	137 (59)	27 (71)	110 (57)	0.1
PedCTAS score[a]	1.9 (0.8)	2.5 (0.8)	1.8 (0.8)	<0.0001
Diagnostic category, *n* (%)				
Respiratory	107 (46)	27 (71)	80 (41)	<0.001
Sepsis	30 (13)	8 (21)	22 (11)	
Trauma	7 (3)	1 (3)	6 (3)	
Neurologic	61 (26)	2 (5)	59 (31)	
Others	26 (11)		26 (14)	

PedCTAS, Pediatric Canadian Triage and Acuity Scale; RPRT, remote presence robotic technology; SD, standard deviation.

transport, 6 (43%) were directed to a regional center and 8 (67%) were triaged to tertiary care. All 193 controls without the RPRT intervention were transported to a tertiary center, and none was regionalized.

For the propensity score matching (*Table 2*), 12 RPRT patients who were not transported were matched with 22 controls. Similarly, 9 RPRT patients who were transported were matched with 31 controls. Together, 21 (55%) of our recruited patients were matched. There were no statistically significant differences between the characteristics of the control and intervention RPRT groups.

Of the matched patients, only nine (43%) required transport, compared to 100% of controls ($p<0.00001$). Furthermore, four of the nine (44%) were regionalized to closer nontertiary health centers, compared to 0% of controls ($p<0.001$). The transported patients had similar LOS (6.0 vs. 5.7 days; $p=0.89$). Finally, the RPRT patients who remained in their community had a significantly shorter hospitalization than controls who were transported (0 vs. 4.9 days; $p<0.001$).

Discussion

The purpose of this novel prospective pilot study was to assess the feasibility of using RPRT at a small clinic in an isolated northern community. Effective care for acutely ill children in remote communities requires access to specialized services to ensure appropriate early intervention and when necessary, high-quality pediatric IFT.[5] Prompt intervention is critical as it has been shown to yield better outcomes and improve survival.[6–8] Furthermore, real-time monitoring and preparedness to modify these interventions are needed, given the potential for the clinical status of acutely ill children to deteriorate rapidly.[6,9,10] We report that the use of RPRT reduced the need for specialized pediatric IFT, while also allowing regionalization when appropriate.

Utilization of RPRT permitted real-time access to a pediatric intensivist, allowing an early diagnosis, intervention, and triage. The resultant decreased utilization of specialized pediatric transport services allowed nearly two thirds of children presenting to the remote clinic to be effectively treated in their home community. This differs from previous practice, where all acutely ill patients from remote communities were transported to higher levels of care. The triaging

Table 2. Demographics and Clinical Characteristics of the Remote Presence Robotic Technology and Control Groups

	NOT TRANSPORTED			TRANSPORTED		
	RPRT	CONTROL	*p*	RPRT	CONTROL	*p*
Propensity score	0.397	0.278	0.15	0.171	0.151	0.37
No. of subjects matched	12	22	N/A	9	31	N/A
Age, months, mean[a]	8.33	8.29	0.99	30.33	27.49	0.15
Male (%)	58	72	0.42	89	92	0.80
PedCTAS score[a]	2.25	1.88	0.11	1.89	1.65	0.45
Respiratory (%)	100	100	1.0	78	73	0.78
Sepsis (%)	0	0	1.0	11	0	0.31
Trauma (%)	0	0	1.0	0	3	0.33
Neurologic (%)	0	0	1.0	11	19	0.58

decisions and interventions recommended using the robot were associated with a sustained and anticipatable outcome, as none of the 24 children treated in the community needed to be transported up to the 14-day reassessment time. In addition to prevented transports, use of RPRT obviated the need for twenty-four 5-day stays in hospital. This reduction in LOS was not observed between transported participants and their controls.

Interestingly, all the intervention patients who were triaged to receive care locally and remain in their home communities for follow-up had a respiratory diagnosis. In order for the local nonspecialized team to effectively treat this population, a certain comfort level with recognition, management, and follow- up of respiratory illnesses was necessary. Having the virtual intensivist present at the initial consult and in follow-up likely provided these elements of supportive and definitive care. Cifuentes et al. found that of the small portion of pediatric patients who had their therapy dramatically altered through telemedicine, 43% had an acute respiratory illness.[21] Together, they may suggest that pediatric respiratory presentations specifically benefit from access to RPRT because of the potential reversibility of clinical trajectories, with aggressive and proper intervention.

In this study, RPRT also permitted the pediatric intensivist to reassess disposition following initiation of therapy, and support the local team until the specialized transport team arrived. During this vulnerable period, ongoing specialist support may have resulted in patient stabilization and reversal of clinical symptoms that affect disposition.[12] The ability to continually reassess clinical status may have assisted the intensivist to confidently triage over 40% of the lower acuity patients to a nearby regional hospital. To compare, none of the control cases was regionalized. This concept of redistribution facilitated family-centered care by allowing more patients to receive care closer to home at a hospital more appropriate for their acuity. Redistribution also has been shown to be a safe way of easing overcapacity issues that often strain tertiary care centers.[32] Given the ability to assess and intervene from afar, RPRT also discouraged the temptation to "scoop and run" patients to tertiary care without first stabilizing them at the referring center.[6] This practice aligns with the substantial evidence for early treatment initiation and ongoing goal-directed resuscitative interventions during pediatric transport to improve outcomes, reduce multiple organ system dysfunction, and reduce LOS.[5–10]

Overall, the use of RPRT has potential for significant cost benefit. The RPRT program costs are limited to an initial robot purchase ($70,000 CAD), a license ($1,200.00/year), hardware support ($7,500.00/year), and a telehealth network ($5,520/year). The robot requires no daily technology support or fees, and is run independently from the laptop of the user. To compare, our traditional provincial telemedicine program has an annual budget of ∼3 million CAD, of which the majority is dedicated to human resource full-time equivalents for daily coordination and technology support. This conventional system currently supports predetermined consultations or follow-up visits, but is less accessible for unpredictable acute/critical care presentations.

Incurred costs must also be weighed against the price of medical transport, as one round-trip specialized pediatric transport in Saskatchewan costs in the range of $10,000 CAD. With our RPRT pilot, there were 24 prevented transports in one small community. This equates to approximately $240,000 CAD in savings. An additional $120,000 CAD (24 patients × $1,000/bed/day × 5 days) was saved through prevented hospitalizations. This totals approximately $360,000 CAD in savings, indicating that the RP-7i paid for itself over five times during the 13-month study period. The prevented transports also reduced costs to families by precluding the need to arrange accommodations, transport, meals, or childcare. However, the remote clinic may have incurred greater cost through managing more patients locally, although these costs were not measured. With ongoing technological advances and less expensive devices, the future of robotic telehealth is exciting.

Utilizing RPRT to refine decision-making around disposition and the need for pediatric healthcare away from home cannot be understated. This is particularly true in First Nations communities, where there is complexity involved in transporting children, which goes beyond medical need or economics and compels us to contemplate indigenous historical trauma and the recommendations of Canada's Truth and Reconciliation Commission (TRC).[33,34] This innovative technology aligns with the TRC by minimizing displacement of indigenous children from their communities and cultures. Barriers to the implementation of RPRT would likely not be technological, but may instead relate to medical liability, jurisdictional legal considerations, provider remuneration, patient confidentiality, and a lack of regional and national telemedicine strategies.[35]

Our study's main limitations included a relatively small study group. Propensity score matching was largely responsible for the size, but we felt that this statistical approach was necessary due to the large number of potential confounders and low number of transports. Second, the pediatric intensivists involved in the RPRT interactions were not blinded, thus introducing potential sources of biases.

Conclusions

RPRT supports a medical delivery system where acutely ill pediatric patients in the periphery receive care in their home community or, when necessary, safe triage to higher levels of care. This technology has the potential to refine our current processes for triaging and patient care redistribution, and may substantially decrease the use of transport services and tertiary care hospitals. By overcoming barriers of geographical distance and time in access to care in rural areas, this innovative technology also addresses a key social determinant of health. This immense potential is furthered by the ability to provide culturally sensitive care in a cost-effective manner. Incorporating this technology into common practice could optimize health services for those in rural and remote areas and be a transformative strategy to mitigate barriers to healthcare access.

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Disclosure Statement

No competing financial interests exist.

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