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Telemedicine Consultations and Medication Errors in Rural Emergency Departments

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Abstract

OBJECTIVE: To compare the frequency of physician-related medication errors among seriously ill and injured children receiving telemedicine consultations, similar children receiving telephone consultations, and similar children receiving no consultations in rural emergency departments (EDs).

METHODS: We conducted retrospective chart reviews on seriously ill and injured children presenting to 8 rural EDs with access to pediatric critical care physicians from an academic children's hospital. Physician-related ED medication errors were independently identified by 2 pediatric pharmacists by using a previously published instrument. The unit of analysis was

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Dr Dharmar conceptualized and designed the study, participated in the conduct of the study and data collection, completed the analyses, interpreted the results, and drafted the manuscript; Drs Kuppermann and Romano conceptualized and designed the study, interpreted the results, and revised the manuscript; Dr Yang assisted with data collection and data analysis, helped interpret the results, and critically reviewed the manuscript; Dr Nesbitt conceptualized and designed the study and critically reviewed the manuscript; Drs Phan and Nguyen determined the data parameters for the study, assisted with data collection, and critically reviewed the manuscript; Dr Parsapour conceptualized and designed the study, participated in the conduct of the study, and revised the manuscript; and Dr Marcin conceptualized and designed the study, participated in the conduct of study, obtained funding, interpreted the results, and revised the manuscript. All authors approved the final manuscript as submitted.

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medication administered. The association of telemedicine consultations with ED medication errors was modeled by using hierarchical logistic regression adjusting for covariates (age, risk of admission, year of consultation, and hospital) and clustering at the patient level.

RESULTS: Among the 234 patients in the study, 73 received telemedicine consultations, 85 received telephone consultations, and 76 received no specialist consultations. Medications for patients who received telemedicine consultations had significantly fewer physician-related errors than medications for patients who received telephone consultations or no consultations (3.4% vs 10.8% and 12.5%, respectively; $P < .05$). In hierarchical logistic regression analysis, medications for patients who received telemedicine consultations had a lower odds of physician-related errors than medications for patients who received telephone consultations (odds ratio: 0.19, $P < .05$) or no consultations (odds ratio: 0.13, $P < .05$).

CONCLUSIONS: Pediatric critical care telemedicine consultations were associated with a significantly reduced risk of physician-related ED medication errors among seriously ill and injured children in rural EDs.

Keywords

emergency medicine; health services research; medication errors; patient safety; pediatrics; telehealth; telemedicine; rural health

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The Institute of Medicine report, *To Err Is Human: Building a Safer Health System*, identified medication errors as one of the most common categories of preventable medical error in hospitals, accounting for >7000 potentially preventable deaths annually.[1] Patients receiving treatment in emergency departments (EDs) are at particularly high risk for experiencing medication errors due to the acute nature of the presenting illness, the importance of timely administration of therapies,[2–6] the chaotic environment, and the lack of oversight to verify medication orders and administration.[7,8] Particularly among children, the risk of medication errors is magnified because of weight-based drug dosing and limited experience among many health care professionals in pediatric prescribing and pharmacotherapy.[2,8–11] Several studies have identified physician prescribing as the most common source of medication errors among children and in EDs.[2,6,9,12–14]

In previous work, we reported high frequencies of medication errors among children treated in rural EDs.[15] Others have found more frequent medication errors among children treated by trainees than among children treated by pediatric attending physicians.[8,16] These findings can be partially attributed to the level of experience and specialized training of physicians and staff caring for seriously ill and injured children.[2,8,16] In addition, infrastructural factors can also contribute to the increased risk of medication errors in rural EDs, such as the lack of electronic medical record systems, computerized physician order entry, medication bar coding, or around-the-clock pharmacist coverage.[3,8,11]

Telemedicine is increasingly used to address some of these shortcomings by providing pediatric specialty consultations to children presenting to rural and underserved EDs as an alternative to telephone consultations.[17–19] Specifically, telemedicine has the potential to prevent medication errors resulting from the lack of access to experienced staff and pediatric specialty expertise.[20–25] The goal of the current study was to evaluate whether

pediatric telemedicine consultations are associated with fewer physician-related medication errors among seriously ill and injured children presenting to rural EDs. We compared the frequency of physician-related medication errors experienced by pediatric patients in the ED receiving pediatric critical care telemedicine consultations with the frequency experienced by similar patients receiving telephone consultations from the same group of specialists and with similar patients receiving no specialist consultations. Our hypothesis was that children whose providers received telemedicine consultations would experience fewer physician-related ED medication errors than children whose providers received telephone consultations or no consultations during their ED visits.

METHODS

Study Design and Setting

This retrospective chart review study was part of a larger investigation of the impact of telemedicine on the quality of care delivered to seriously ill and injured children presenting to rural EDs in northern California. Eight rural EDs were selected (non-random) to receive telemedicine as an intervention during the study period. Critical-access hospital EDs were selected because of their limited experience in treating seriously ill and injured children and the likelihood that telemedicine consultations would potentially have a greater impact on quality of care at these hospitals. All of the study hospitals were located in designated rural areas, as defined by California's Office of Statewide Health Planning and Development[26] and the federal Centers for Medicare & Medicaid Services,[27] and were within University of California Davis Children's Hospital's referral region. The study hospitals were also located in "underserved" communities, according to the Health Resources and Services Administration's definitions of Health Professional Shortage Areas, Medically Underserved Areas, and Medically Underserved Populations.[27,28] The participating rural EDs treat between 4000 and 10 000 patients annually, including 10 to 30 seriously ill and injured children, and had existing relationships with University of California Davis Children's Hospital to have around-the-clock access to pediatric critical care consultations by telephone. None of the study hospitals had computerized physician order entry systems, used software to verify dosing or administration technique, or had a system for verifying allergies or contraindications to medications. All participating EDs also dispensed medications without pharmacist involvement.

Telemedicine Equipment

Pole-mounted telemedicine systems were installed at the 8 participating EDs on a rolling basis between 2003 and 2007. The telemedicine systems included a turnkey videoconferencing unit (either Polycom, Inc or Cisco Systems, Inc [San Jose, CA]), a flat-screen, high-resolution monitor, and an uninterrupted power supply. The videoconferencing unit provided bidirectional video using a high-definition camera capable of pan, tilt, and zoom functions. Our clinicians did not use any peripheral devices such as digital stethoscopes, otoscopes, or ophthalmoscopes.

Telemedicine and Telephone Consultations

Pediatric critical care physicians were available around-the-clock for both telemedicine and telephone consultations. When a remote ED physician desired a pediatric critical care consultation, he or she would call a toll-free number. The critical care physician would then be contacted by pager and would provide consultation to the referring ED physician either over telemedicine or a bridged telephone call.

Telemedicine consultations involved live, interactive audiovisual communications between the referring rural ED physician, the pediatric patient, the ED nurse, the parent/guardian (if available), and the academic children's hospital pediatric critical care physician. In the event that the in-house physician was unable to provide the consultation, a "backup" attending physician was designated at all times. All backup physicians had access to desktop and/or laptop computer-based videoconferencing systems that allowed them to conduct telemedicine calls while away from the hospital.

Selection of Patients

This study included children aged >1 day and <17 years who presented to one of the participating EDs between January 1, 2003, and December 31, 2009, and were triaged in the highest category at presentation (ie, seriously ill or injured). All of the participating EDs had similar 3-level triage systems. The study protocol recommended the use of telemedicine for all children presenting to the ED in this highest triage category, but the final decision was made by the rural ED physician, including whether a telemedicine or telephone consultation was to be used. Eligible patients were identified retrospectively after reviewing the paper and/or electronic logs from the participating EDs. The medical records of these patients were then reviewed to determine if the patients received a pediatric critical care consultation.

For all children meeting eligibility criteria, we used consecutive sampling of records with telemedicine consultations and a random sample of records with telephone consultations and no specialist consultations to ensure a similar number of patients in each group. The medical records for the study patients were copied by a research assistant, who ensured that any information related to the telemedicine or telephone consultation was obscured (ie, blacked out) so that reviewers were neither aware of nor influenced by the type of consultation obtained by the rural ED physician.

Medication Error Ascertainment

We used a previously published medication error instrument to identify and categorize medication errors by using retrospective chart review.[15] This instrument evaluated all medications administered in the ED. The medication error instrument was applied to all medical records independently by two pediatric pharmacists who were not involved in the care of the study participants, according to previously published guidelines. Discrepancies between the reviewers'assessments of whether there was a medication error were resolved by both pharmacists together in the presence of a pediatric critical care physician.
We focused on physician-related ED medication errors because we hypothesized that telemedicine and telephone consultations would most likely affect errors related to ED physician prescribing. We defined physician-related ED medication errors a priori as those

involving a wrong dose, a wrong or inappropriate medication for the patient's condition, a wrong route of administration, a wrong dosage form, and errors related to drug interaction information as well as errors regarding patient information, such as a known allergy.

Outcome Variables and Factors Likely Related to Medication Errors

Our primary outcome variable was physician-related ED medication errors. The research assistant abstracted information about factors that might be related to the risk or incidence of medication errors, including patient age and gender, year of consultation, method of arrival (walk-in or Emergency Medical Services transport), weekend admission (Friday 7 PM to Monday 7 AM), disposition (observed in ED, discharged from the hospital, admitted, transferred, or died), Pediatric Risk of Admission II (PRISA II) score,[29] and type of consultation (telemedicine, telephone, or no consultation).

Statistical Analysis

We compared the baseline characteristics of patients who received telemedicine consultations, patients who received telephone consultations, and patients who received no consultations by using an analysis of variance. A Bonferroni correction was applied for multiple comparisons to compare differences among the groups when the global F test was significant ($P < .05$). We compared categorical variables by using the χ^2 test and Fisher's exact test, as appropriate. The unit of analysis was individual medication administered, such that individual patients could have zero or >1 medication included in the analyses. Patient gender, weekend admission, ED arrival method, and disposition of care were considered for inclusion as risk adjustors. All of the explanatory variables were assessed by using a correlation matrix to determine collinearity before including them in the model. The Akaike Information Criterion was used for model selection. We decided, a priori, to include age, the PRISA II score (risk of admission), and hospital in the multivariable model. We also decided a priori to include a temporal measure (year of consultation) to adjust for the effect of any secular trend in the care provided to these children. A hierarchical logistic regression model with patient-level random effects was used to estimate odds ratios (ORs) and 95% confidence intervals for the association between physician-related medication error and types of consultation.

Human Subjects

The study was approved by the Human Subjects Review Committees at the primary academic hospital and all of the participating hospitals.

RESULTS

A total of 234 pediatric patients were retrospectively evaluated for medication errors by the pharmacists. For the telemedicine cohort, we included all 73 (100%) children who received pediatric critical care telemedicine consultations. For the telephone and no consultation cohorts, we randomly sampled 85 (88.5%) of the 96 children who received pediatric critical care telephone consultations, and 76 (22.6%) of the 336 children who received no pediatric critical care consultations, respectively. Table 1 describes the characteristics of the study sample. Patients were similar when stratified based on consultation type (telemedicine,

telephone, or no consultation) except for some baseline demographic variables, including race, which was unknown (not documented) in 83 (35.5%) patients. Patients who received no consultations were older than children who received telemedicine and telephone consultations. Children who received telephone consultations had a significantly higher mean PRISA II score than children who received no consultations.

Of the 234 patients, 168 (71.8%) received at least 1 medication while in the ED. Thirty patients (12.8% of all patients, 17.9% of patients who received at least 1 medication) were identified as having at least 1 physician-related ED medication error. Among the 73 patients who received telemedicine consultations, 56 (76.7%) received at least 1 medication while in the ED, of whom 4 (7.1%) were identified as having at least 1 physician-related ED medication error. Among the 85 patients who received telephone consultations, 58 (68.2%) received at least 1 medication while in the ED, of whom 15 (25.9%) were identified as having at least 1 physician-related ED medication error. Among the 76 patients who received no consultations, 54 (71.1%) received at least 1 medication while in the ED, of whom 11 (20.3%) were identified as having at least 1 physician-related ED medication error.

A total of 441 medications were administered to study patients, with 146 (33.1%) administered to patients receiving telemedicine consultations, 167 (37.9%) administered to patients receiving telephone consultations, and 128 (29.0%) administered to patients receiving no consultations. Among the 441 medications administered, 39 (8.8%) were identified as having at least 1 physician-related ED medication error. As shown in Table 2, there were significant differences in the risk of a physician-related ED medication error among the 3 cohorts ($P < .05$). Patients who received telemedicine consultations had significantly fewer physician-related ED medication errors (3.4%) than patients who received telephone consultations (10.8%) and no consultations (12.5%) (both, $P < .05$). Among the administered medications, the most common type of error was wrong dose (4.1% of all administered medications). Patients who received telemedicine consultations had significantly fewer wrong dose medication errors (0.7%) than patients who received telephone consultations (6.6%, $P < .05$) and no consultations (4.7%, $P = .053$).

In the bivariate analyses with administered medications as the unit of analysis, patients who received telemedicine consultations were less likely to have physician-related ED medication errors than patients who received telephone consultations (OR: 0.29, $P < .05$) and no consultations (OR: 0.25, $P < .05$). None of the other independent variables (including age, patient gender, race, weekend admission, year of consultation, PRISA II score, hospital, or mode of arrival to the ED) was significantly associated with physician-related medication errors.

Table 3 shows the results of the multivariable analysis, adjusting for clustering at the patient level. After adjusting for age, risk of admission (PRISA II score), year of consultation, and hospital, patients who received telemedicine consultations were less likely to have physician-related ED medication errors than patients who received no consultations (OR: 0.13, $P < .05$). In the same multivariable analysis, patients who received telemedicine consultations were less likely to have physician-related ED medication errors than patients who had telephone consultations (OR: 0.19, $P < .05$).

DISCUSSION

In this cohort of seriously ill and injured children treated in 8 rural EDs, physician-related medication errors were less frequent in patients who received telemedicine consultations (3.4% medication error rate) than among patients who received no consultation (12.5% mediation error rate) or who received telephone consultations (10.8% medication error rate). This lower incidence of physician-related ED medication errors was identified despite the fact that children were younger in the telemedicine cohort than in the other cohorts. In our multivariable analysis, adjusting for patient age, risk of admission, year of consultation, and hospital, we found lower odds of physician-related ED medication errors when consultations were conducted with the use of telemedicine. The lower frequency of medication errors associated with telemedicine consultations was observed both when we used the individual patient and the individual medications administered as the unit of analysis.

Our finding of 12.8% risk for physician-related medication errors among children treated in our study EDs is similar to the risk (12%–24%) reported in previous studies.[2,5,13] Errors in dosing were the most common type, consistent with previous studies involving children in other acute care settings.[3–6,8,11,13] These studies attributed dosing errors in children to the chaotic environment in EDs and the lack of sufficient provider training and knowledge in calculating medication doses for children.[3–6,8,11,13]

Our finding of lower physician-related ED medication errors among patients who received telemedicine consultations could be attributed to the specialized training and higher level of experience among the consulting physicians in treating children, which is consistent with other studies evaluating the impact of physician training and experience on patient outcomes.[8,15,30–33] Kozer et al,[8] who examined medication errors experienced by children in an ED, found that trainees who do not have sufficient experience in treating children are more likely to commit prescribing errors than attending physicians.[8] Charash et al[30] examined the impact of telemedicine on simulated rural trauma patients in a moving ambulance and found that telemedicine resulted in better assessments, more interventions, and better patient outcomes than radio consultations. Several studies have associated delays in pediatric diagnosis and inappropriate pediatric management with the unavailability of pediatric specialists.[15,31–33] These studies suggest that telemedicine consultations may reduce the risk of medication errors by enabling improved assessments and therapeutic recommendations by specialists experienced in the care of seriously ill and injured children.

Telemedicine consultations were associated with significantly fewer physician-related medication errors than telephone consultations, consistent with other intervention studies aimed at preventing medical errors in children.[34–37] These findings could reflect the fact that patients receiving telemedicine consultations have more involvement of the consulting specialist than patients receiving telephone consultations and the ability of the consulting physicians to see the patient during the consultation. In our experience, the pediatric specialist spends more time on a telemedicine consultation call than on a telephone consultation call, although precise time estimates are not available. In a recent systematic review, Kaufmann et al[38] reported that measures focused on improving a provider's

experience, and aids focused on improving the medication-ordering process, can effectively reduce the risk of medication errors in children.

This study has several limitations. In a retrospective chart review study, the identification and assessment of medication errors are dependent on the level of documentation in the medical record. However, this problem would have affected all consultation cohorts, given that neither telemedicine nor telephone consultants documented directly in the referring hospital's medical record. Also, as a consequence of our inability to consistently identify intercepted errors in this study, we could not evaluate the impact of telemedicine consultation on intercepted errors experienced in the ED. Furthermore, we were unable to determine the time of consultations in relation to the medication errors. Therefore, the observed relationship between telemedicine consultations and lower frequency of medication errors is only an association and cannot be assumed to be causal. Because our study hospitals may not be representative of other rural EDs or community hospitals, our findings are subject to potential selection bias. At rural EDs with computerized physician order entry, automated alert algorithms, or around-the-clock pharmacist availability, telemedicine consultations may have less of an impact on medication errors. The clinical significance of medication errors varies; it is not clear whether the observed association would lead to improved patient outcomes or reduced health care costs. Most importantly, this study was not a randomized trial and is therefore subject to potential confounding bias. The study patients in different cohorts may have differed on unobserved characteristics or confounders that explained the observed differences in physician-related medication errors, although we adjusted for observable confounders in our multivariable analysis.

This study also has several strengths. To the best of our knowledge, it is the first study to evaluate the impact of telemedicine consultations on physician-related ED medication errors. Second, we used a robust method for evaluating medication errors, having two pharmacists review medical charts by using a previously validated medication error instrument that was specifically developed for children. Lastly, this study is consistent with previous research which has demonstrated that specialty telemedicine consultations can result in improved patient safety.[18,39–44]

CONCLUSIONS

The use of telemedicine to provide pediatric critical care consultations to rural EDs was associated with significantly fewer physician-related medication errors than providing critical care consultations by telephone or providing care to similarly ill children without pediatric critical care consultations. This reduction in medication errors can potentially lead to improved outcomes and/or lower health care costs, although our study does not directly address these questions. Consequently, the use of telemedicine to provide pediatric specialty consultations may be a means to improve patient access to specialists and increase safety for seriously ill or injured children receiving emergency care in rural, underserved hospitals.

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ABBREVIATIONS

ED	emergency department
OR	odds ratio
PRISA II	Pediatric Risk of Admission II

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WHAT'S KNOWN ON THIS SUBJECT:

Medication errors occur frequently among pediatric patients, particularly those treated in rural emergency departments (EDs). Although telemedicine has been proposed as a potential solution, there are few data supporting its clinical effectiveness and its effect on medication errors.

WHAT THIS STUDY ADDS:

The use of telemedicine to provide pediatric critical care consultations to rural EDs is associated with less frequent physician-related ED medication errors among seriously ill and injured children. Therefore, this model of care may improve patient safety in rural hospital EDs.

TABLE 1

Demographic Characteristics of Children Receiving Telemedicine Consultations, Telephone Consultations, and No Consultations

Characteristic	Total	Telemedicine	Telephone	No Consultations
Age, mean ± SD, y[a,b]	5.2 ± 5.1	3.7 ± 4.3	5.1 ± 5.1	6.7 ± 5.8
Gender				
Male	140 (59.8)	45 (61.6)	44 (51.8)	51 (67.1)
Female	94 (40.2)	28 (38.4)	41 (48.2)	25 (32.9)
Race/ethnicity[a,c]				
White	98 (41.9)	39 (53.4)	30 (35.3)	29 (38.2)
African American	8 (3.4)	0	3 (3.5)	5 (6.6)
Asian	2 (0.9)	1 (1.4)	1 (1.2)	0
Hispanic	43 (18.4)	19 (26.0)	17 (20.0)	7 (9.2)
Other	83 (35.5)	14 (19.2)	34 (40.0)	35 (46.1)
Weekend admission				
No	180 (76.9)	61 (83.6)	65 (76.5)	54 (71.1)
Yes	54 (23.1)	12 (16.4)	20 (23.5)	22 (28.9)
Patients arriving by Emergency Medical Services transport				
No	169 (72.2)	58 (79.5)	58 (68.2)	53 (69.7)
Yes	65 (27.8)	15 (20.5)	27 (31.8)	23 (30.3)
Disposition of care				
Observed	15 (6.4)	4 (5.5)	4 (4.7)	7 (9.2)
Sent home	73 (31.2)	23 (31.5)	32 (37.6)	18 (23.7)
Admitted	68 (29.1)	20 (27.4)	26 (30.6)	22 (28.9)
Transferred	72 (30.8)	23 (31.5)	22 (25.9)	27 (35.5)
Died	6 (2.6)	3 (4.1)	1 (1.2)	2 (2.6)
PRISA II score (mean, SD)[b]	12.7 (12.6)	11.9 (12.0)	15.7 (13.3)	10.0 (11.7)

Bonferroni correction was applied to adjust for multiple comparisons. Data are presented as mean ± SD or *n* (%).

[a] $P < .05$ patients receiving telemedicine consultations compared with no consultation.

[b] $P < .05$ patients receiving telephone consultations compared with no consultation.

[c] $P < .05$ patients receiving telemedicine consultations compared with telephone consultations.

TABLE 2

Type and Frequency of Physician-Related ED Medication Errors in Children Who Received Telemedicine Consultations, Telephone Consultations, or No Consultations

Medication Error Type	Total (*N* = 441)	Telemedicine (*n* = 146)	Telephone (*n* = 167)	No Consultations (*n* = 128)
Wrong dose[a]	18 (4.1)	1 (0.7)	11 (6.6)	6 (4.7)
Too large a dose	11 (2.5)	1 (0.7)	7 (4.2)	3 (2.3)
Too little a dose	7 (1.6)	0	4 (2.4)	3 (2.3)
Wrong or inappropriate drug administered for condition	17 (3.9)	3 (2.1)	5 (3.0)	9 (7.0)
Wrong route	0	0	0	0
Wrong dosage form	2 (0.5)	1 (0.7)	1 (0.6)	0
Error related to patient information	2 (0.5)	0	1 (0.6)	1 (0.8)
Total medication errors[a,b]	39 (8.8)	5 (3.4)	18 (10.8)	16 (12.5)

Medication administered is the unit of analysis. Bonferroni correction was applied to adjust for multiple comparisons.

[a] $P < .05$ patients receiving telemedicine consultations compared with telephone consultations.

[b] $P < .05$ patients receiving telemedicine consultations compared with no consultations.

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TABLE 3

Multivariable Analysis of the Association Between Physician-Related ED Medication Errors and Type of Consultation

Variable	OR	95% CI
Age	0.99	0.89–1.09
PRISA II score	1.01	0.98–1.05
Year of consultation	1.07	0.74–1.53
Hospital		
A	Ref	
B	0.17	0.02–1.40
C	0.77	0.18–3.18
D	1.18	0.19–7.06
E	0.49	0.09–2.59
F	8.58	0.00–9.00
G	0.34	0.03–4.85
H	0.16	0.02–1.76
Consultation type		
No consultation	Ref	
Telephone	0.82	0.25–2.67
Telemedicine	0.13[a]	0.02–0.74

Medication administered is the unit of analysis. $N = 441$ medications. CI, confidence interval.

[a] $P < .05$.