

## Association of a Remotely Offered Infectious Diseases eConsult Service With Improved Clinical Outcomes

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We performed a case-control study to evaluate an electronic, asynchronous infectious diseases consultative service at 2 rural hospitals within our health system. Patients with consultation via this platform ( $n = 100$ ) had a significantly decreased odds of death at 30 days compared with propensity-matched controls ( $n = 300$ ; adjusted odds ratio, 0.3; 95% confidence interval, 0.2–0.7;  $P = .003$ ).

**Keywords.** infection; infectious diseases; sepsis; telemedicine.

Numerous studies have demonstrated that infectious diseases (ID) consultation is associated with improved outcomes for hospitalized patients [1–3]. However, the supply of ID specialists may not meet the current or anticipated demand [4]. Smaller hospitals may not have the demand needed to justify the sustained presence of dedicated on-site ID specialists. Patients hospitalized in such settings are at higher risk of receiving suboptimal ID care.

Telemedicine presents an opportunity to expand the role of ID specialists outside of face-to-face evaluations. Real-time, interactive telemedicine consultation improves outcomes in hospitalized patients [5]. However, synchronous electronic consultation requires dedicated telemedicine equipment, staffing at the referring hospital to facilitate the consultation, and temporal coordination between the referring and consulting facilities. These requirements may limit the expansion of real-time telemedicine, particularly in critical access hospitals, where the need is greatest.

Asynchronous telemedicine (eConsultation) avoids the logistical hurdles of real-time telemedicine and has been used extensively for outpatients worldwide [6]. This platform improves timely access to specialty care and decreases costs [7]. Although primarily used for outpatient evaluations, eConsults are feasible for inpatients, particularly in health systems with a unified electronic health record (EHR) that facilitates rapid turnaround. We sought to evaluate the impact of a newly established eConsult service for patients hospitalized for infection on patient- and provider-level outcomes at our institution.

### METHODS

At the time of this study, Mayo Clinic Health System (MCHS) Austin Hospital and MCHS Albert Lea Hospital were 159-bed and 129-bed hospitals, respectively, located in Southeastern Minnesota. Mayo Clinic Rochester (MCR) is a tertiary referral center located in Rochester, Minnesota. All MCHS sites and MCR utilize a single unified EHR. Historically, patients needing ID care were managed via telephone curbside consultation with ID specialists at MCR. On July 2, 2018, ID specialists at MCR began performing asynchronous eConsults for adult patients hospitalized at MCHS Austin and MCHS Albert Lea Hospital. A consult was requested via page or email to a designated ID specialist at MCR. The ID specialist reviewed the EHR and placed a consult note in the EHR of the referring hospital within 24 hours. If further information was needed to provide consultative advice, the ID specialist and referring provider would communicate either electronically or via telephone. Consults requested before 2 PM were performed the same day, although weekend eConsults were only available for the first 6 weeks of the program. Patients with ongoing needs had subsequent daily review of their records documented in progress notes placed into the EHR.

To evaluate the impact of the eConsults, we performed a retrospective, propensity-matched, case-control study. The study was reviewed by the institutional review board (IRB) and deemed exempt from IRB approval. The first 100 consecutive inpatients evaluated with eConsultation from July 2018 through December 2018 were identified as cases. A pool of potential controls was created using hospital census reports to identify patients admitted with an ID diagnosis during the 8 months before initiation of the eConsult program (Supplementary Appendix). Propensity scores were derived using logistic regression to model the likelihood of receiving the intervention using predictors of patient age at admission, gender, race, and weighted Charlson Comorbidity Index (wCCI) to account for comorbidities including myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular

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disease, dementia, chronic pulmonary disease, ulcer, liver disease, diabetes, hemiplegia, renal disease, metastatic solid tumor, rheumatologic disease, and other cancer. Controls were sampled sequentially and optimally matched to cases based on the absolute difference in propensity score in order to gain balance with covariates, thereby removing the effect of baseline differences between cases and controls, resulting in a 1:3 sampling ratio. Balance of covariates between matched cases and controls was confirmed by assessing standardized differences of baseline patient characteristics pre- and postmatch. Logistic regression models were used to assess the association of the intervention with the primary outcome (30-day mortality) and secondary outcomes (30-day readmissions and hospital transfers) among matched cases and controls. Prior hospitalization has been shown to be a strong determinant of next admission and was also included as a controlling factor in models [8]. Adjusted odds ratios (aORs) and associated 95% confidence intervals (95% CIs) were calculated. All data management and statistical analyses were performed using Statistical Analysis Software (SAS), version 9.4 (Cary, NC, USA).

In addition to the patient-level outcomes, we evaluated the experience of referring providers and the consulting ID specialists during the 6-week pilot period. Within 1–2 days after each consultation, a survey was sent to the referring hospitalist. This survey used a 5-point Likert scale ranging from “very dissatisfied” to “very satisfied” to evaluate a variety of process measures (Supplementary Appendix). Information was collected from the ID consultants at the time of consultation regarding the interventions recommended, the appropriateness of each patient for eConsultation, and the work required for this service (Supplementary Appendix).

Survey data were recorded and managed using the Research Electronic Data Capture system [9]. Research Electronic Data Capture is a secure web-based application designed to support data capture for research studies. Survey data were summarized using count and proportion by response category.

## RESULTS

A total of 300 controls hospitalized from November 2017 through June 2018 were matched to the cases ( $n = 100$ ) and included in the analyses (Table 1).

The average age of patients included in the study was  $69.7 \pm 18.7$  years, with a slight female majority (55%). The population was predominantly Caucasian (94%), with a mean wCCI score of  $7.5 \pm 4.5$ . These attributes were well matched between cases and controls. Univariate regression, controlling for propensity score, showed that cases were 4 times more likely to have been hospitalized in the preceding 6 months, compared with controls (OR, 4.1; 95% CI, 2.4–6.9;  $P < .01$ ).

Logistic regression, with adjustment for the match and hospitalization in the preceding 6 months, showed that cases who received ID eConsultation had a reduced risk of death

within 30 days, as compared with controls (aOR, 0.3; 95% CI, 0.2–0.7;  $P < .01$ ). There was a trend toward decreased readmission within 30 days for the cases, as compared with controls (aOR, 0.4; 95% CI, 0.2–1.1;  $P = .07$ ). The reason for readmission was related to infection in 3 of 6 readmitted cases and 21 of 33 readmitted controls. There was no difference in the overall rate of hospital transfer between cases and controls (aOR, 1.4; 95% CI, 0.6–3.7;  $P = .50$ ). The number of patients transferred for care related to infection was similar between cases ( $n = 4$ , 4%) and controls ( $n = 14$ , 4.7%). Cases were significantly more likely to have a longer length of stay (OR, 1.3; 95% CI, 1.2–1.5;  $P < .01$ ). The mean hospital length of stay for the cases was 5.7 days, compared with that of controls (3.8 days). However, ID eConsultation did not occur until on average 2.6 days into the hospitalization.

During the first 6 weeks of the service (pilot period), 19 hospitalists requested an eConsultation for 36 individual patients who were evaluated a total of 64 times. Eighteen of 19 hospitalists (95%) were “very satisfied” with the overall experience, whereas the remaining provider was “satisfied” with the overall experience. All providers were “very satisfied” with the ease of placing the consult and the use of the EHR in the process. Seventeen of 19 hospitalists (89%) were “very satisfied” with communication on next steps in the patient’s care, the time it took to receive the consult information, and the level of explanation from the ID specialist. There were 6 unique ID specialists who performed eConsultations during the 6 weeks of the pilot. On average, each initial eConsultation took 29 minutes (range, 8–66 minutes), whereas a follow-up evaluation took 9 minutes (range, 2–15 minutes). The initial interventions recommended included antibiotic type change (94%), antibiotic duration change (55%), antibiotic deescalation (48%), additional laboratory testing (48%), and consultation with services other than infectious diseases (6%). Transfer to MCR was recommended in 1 of 36 patients (3%). Overall, all ID specialists felt that this service added value to the patients’ care.

## DISCUSSION

This is the first study to describe the use of asynchronous ID eConsults for hospitalized patients and to assess its impact on mortality, readmission, and hospital transfer. Compared with matched controls, we demonstrate a 70% reduction in 30-day mortality for patients who were managed with the assistance of ID eConsultation. Additionally, a trend toward decrease in 30-day readmission was observed without an increase in hospital-to-hospital transfer.

Cost and technical challenges are major barriers to the widespread adoption of telemedicine [10]. Synchronous telemedicine allows for real-time, interactive evaluation of the patient, including remote physical exam and patient interview. Although this may be beneficial in some patients, ID evaluations often rely upon interpretation of objective medical data that do not

**Table 1. Demographics and Outcomes of Cases and Propensity-Matched Controls**

	Cases (n = 100)	Controls (n = 300)	Total (n = 400)
Age, mean (SD), y	69.5 (17.7)	69.8 (19.0)	69.7 (18.7)
Gender, No. (%)			
Female	53 (53.0)	169 (56.3)	222 (55.5)
Male	47 (47.0)	131 (43.7)	178 (44.5)
Race, No. (%)			
White	94 (94.0)	282 (94.0)	376 (94.0)
Other	6 (6.0)	18 (6.0)	24 (6.0)
Weighted Charlson Comorbidity Index Score, mean (SD)	7.5 (4.7)	7.5 (4.4)	7.5 (4.5)
Hospitalization during previous 6 mo, No. (%)			
No	56 (56.0)	248 (82.7)	304 (76.0)
Yes	44 (44.0)	52 (17.3)	96 (24.0)
Hospital transfer, No. (%)	10 (10.0)	19 (6.3)	29 (7.3)
Length of stay, mean (SD), d	5.7 (3.6)	3.8 (2.3)	4.3 (2.8)
Readmission within 30 d, No. (%)	6 (6.0)	33 (11.0)	39 (9.8)
Death within 30 d, No. (%)	11.0 (11.0)	66 (22.0)	77 (19.3)

require interactive patient evaluation. We deliberately chose to pursue an asynchronous approach that minimizes barriers to implementation. eConsultation is easily scalable and requires minimal capital investment or ongoing time commitment on the part of the referring facility, which is particularly apropos to rural or critical access hospitals. We developed infrastructure within our consultative practice to facilitate same-day evaluation, which is critical to timely evaluation of acutely ill patients. Recognizing the limitations and strengths of each approach, we feel that the future of ID telemedicine should include a variety of options individualized to the complexity and needs of each individual patient and the capabilities of the health care facility. Ideally, hospitals without in-person ID support should have a readily available electronic antimicrobial stewardship program, asynchronous eConsultation, synchronous video telemedicine, and available hospital-to-hospital transfer for in-person ID consultation to provide a full spectrum of ID care.

Although we did not observe a significant difference in the frequency of hospital transfers, we did observe an increase in the length of stay for patients who had ID eConsultation. Previous studies have suggested that ID consultation early during hospital stay is associated with improved outcomes and shorter length of stay [2]. Our observation suggests that encouraging eConsultation early during hospital stay would not only decrease total length of stay, but may also improve outcomes.

We observed a high degree of satisfaction with the service provided, within both the referring hospitalists and the ID specialists. The asynchronous process allowed for minimal disruption of the referring provider schedule, effectively occurring in the background of the patient care activities. From the ID specialist standpoint, the ability to add this service into routine daily clinical practice at the temporal discretion of the specialist is particularly attractive. Given the positive feedback and

flexibility of this service, this service was incorporated into 1 of our outpatient calendars, with the anticipated time need based on the volumes observed during the pilot.

There are several important limitations of this study. We utilized a case-control design performed within the same 2 hospitals to minimize the impact of unrecognized variables on the findings. Nevertheless, it is certainly possible that unmeasured confounders could have differentially contributed to cases and controls. The sequential nature of the study, where control patients were hospitalized before case patients, may contribute to differences in routine clinical practice that occurred during that time period. We sought to mitigate those differences between the 2 groups of patients by performing propensity matching and adjustment of the models based on the frequency of previous hospitalization in the 2 groups. Given the limitations outlined here, these data should be cautiously interpreted until asynchronous eConsultation can be carefully studied in further prospective studies.

In summary, asynchronous ID eConsultation is a viable option for hospitals without in-person ID consultation. ID eConsultation is associated with a decrease in 30-day mortality, no increase in hospital-to-hospital transfer, and a high level of satisfaction from referring providers.

#### Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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## References

1. McQuillen DP, MacIntyre AT. The value that infectious diseases physicians bring to the healthcare system. *J Infect Dis* **2017**; 216:588–93.
2. Schmitt S, MacIntyre AT, Bleasdale SC, et al. Early infectious diseases specialty intervention is associated with shorter hospital stays and lower readmission rates: a retrospective cohort study. *Clin Infect Dis* **2019**; 68:239–46.
3. Schmitt S, McQuillen DP, Nahass R, et al. Infectious diseases specialty intervention is associated with decreased mortality and lower healthcare costs. *Clin Infect Dis* **2014**; 58:22–8.
4. Walensky RP, Del Rio C, Armstrong WS. Charting the future of infectious disease: anticipating and addressing the supply and demand mismatch. *Clin Infect Dis* **2017**; 64:1299–301.
5. Monkowski D, et al. A retrospective cohort study to assess the impact of an inpatient infectious disease telemedicine consultation service on hospital and patient outcomes. *Clin Infect Dis* **2019**; pii: ciz293.
6. Liddy C, Moroz I, Mihan A, et al. A systematic review of asynchronous, provider-to-provider, electronic consultation services to improve access to specialty care available worldwide. *Telemed J E Health* **2019**; 25:184–98.
7. Liddy C, Drosinis P, Deri Armstrong C, et al. What are the cost savings associated with providing access to specialist care through the Champlain BASE eConsult service? A costing evaluation. *BMJ Open* **2016**; 6:e010920.
8. Donzé J, Aujesky D, Williams D, Schnipper JL. Potentially avoidable 30-day hospital readmissions in medical patients: derivation and validation of a prediction model. *JAMA Intern Med* **2013**; 173:632–8.
9. Harris PA, Taylor R, Thielke R, et al. Research Electronic Data Capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* **2009**; 42:377–81.
10. Scott Kruse C, Karem P, Shifflett K, et al. Evaluating barriers to adopting telemedicine worldwide: a systematic review. *J Telemed Telecare* **2018**; 24:4–12.