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Use of teledermatology by dermatology hospitalists is effective in the diagnosis and management of inpatient disease.

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CAPSULE SUMMARY

- Inpatient access to dermatologists is limited, highlighting an opportunity to utilize teledermatology within the inpatient setting.
- Teledermatology in the inpatient setting may be a clinically acceptable option for diagnosis, evaluation, and management. This may represent a novel and effective option for hospitals.

ABSTRACT:

Background: Patient outcomes are improved when dermatologists provide inpatient consults. Inpatient access to dermatologists is limited, illustrating an opportunity to utilize teledermatology. Little is known about the ability of dermatologists to accurately diagnose and manage inpatients using teledermatology, particularly utilizing non-dermatologist generated clinical data.

Methods: This prospective study assessed the ability of teledermatology to diagnose and manage 41 dermatology consults from a large urban tertiary care center utilizing internal medicine referral documentation and photos. Twenty-seven dermatology hospitalists were surveyed. Interrater agreement was assessed by the kappa statistic.

Results: There was substantial agreement between in-person and teledermatology assessment of the diagnosis with differential diagnosis (median kappa = 0.83), substantial agreement in laboratory work-up decisions (median kappa = 0.67), almost perfect agreement in imaging decisions (median kappa = 1.0), and moderate agreement in biopsy decisions (median kappa = 0.43). There was almost perfect agreement in treatment (median kappa = 1.0), but no agreement in follow-up planning (median kappa = 0.0). There was no association between raw photo quality and the primary plus differential diagnosis or primary diagnosis alone.

Limitations: Selection bias and single-center nature.

Conclusions: Teledermatology may be effective in the inpatient setting, with concordant diagnosis, evaluation, and management decisions.

BACKGROUND:

Teledermatology is the remote dermatologic assessment of patients, in real-time ("live interactive"), by accessing stored data ("store-and-forward"), or a combination of the two ("hybrid"), with worldwide applications.(1) Teledermatology has been studied in general triage, consultation in remote locations, and monitoring of chronic skin conditions.(1) In addition to increased access to dermatologists, potential benefits of store-and-forward teledermatology include cost reduction due to fewer face-to-face (FTF) consultations,(2) reduced travel time and opportunity cost due to missed work,(3-5) and reduced contagion spread amid infectious disease outbreaks.

Significant clinical evidence supports the outpatient use of store-and-forward teledermatology.(2-10) In contrast, teledermatology has been studied in the inpatient setting to a limited degree. A significant practice gap exists between the demand for inpatient dermatology services and access to dermatologists,(11, 12) often a source of frustration for inpatient providers and patients. Dermatology hospitalists represent a clinical group with expertise in complex medical dermatology and the diagnosis and management of skin diseases affecting hospitalized patients. Involvement of dermatology hospitalists in the care of hospitalized patients has been found to improve patient outcomes.(13) In a subset of cases, inpatient teledermatology reduces time for the primary medical team to receive a response for a dermatology consultation.(14) Dermatologist interest in inpatient teledermatology is high. A survey of attending dermatologists demonstrated that 61.5% agreed or strongly agreed that teledermatology helps inpatient care.(15) Another study found that 95% of hospital and emergency department practitioners would utilize a teledermatology consult service if available, however only 5% believed that teledermatology would be equivalent to a face-to-face (FTF) consult.(16) This finding supports the need for

additional studies evaluating inpatient teledermatology, which may shift perception and encourage adoption of inpatient teledermatology.

This study investigates the diagnostic and management agreement between inpatient FTF and store-and-forward teledermatology evaluations utilizing remote digital evaluations for hospital-based dermatology consultations.

METHODS

Eligible patients for this study were admitted to Massachusetts General Hospital between July and August 2013 and had a dermatology consultation staffed by a dermatology hospitalist with more than six years of inpatient experience, defined as the Primary Dermatologist (PD). This yielded a sample of 108 patients. Only those consultations with digital images and non-dermatology evaluations involving the dermatologic complaint were included. Cases were selected if the accuracy of the PD's diagnosis was able to be confirmed based on testing, response to therapy and final diagnosis at discharge. Based on these inclusion criteria, a total of 42 patients were initially included (Figure 1). One case was excluded from analysis to preserve the generalizability of study results,(17) as this patient presented with multiple concomitant dermatologic complaints and the documentation did not specify the specific focus of the dermatology consultation.

For teledermatology review, data abstractors not involved in the care of the included cases packaged patient data into surveys by unique numerical patient identifiers. Each survey set contained seven individual cases, randomly assigned to each survey set from the total case pool. Each individual case contained the relevant history and physical exam notes generated by a non-dermatologic internal medicine or emergency medicine provider. In addition, all data such as laboratory studies, imaging, microbiology, pathology, and digital images up to the day of the

consult that would have been available to the PD were included. Finally, a diagnosis/management questionnaire was included. The order of case examination within each survey set was fixed across all TDs. Patient identifiers were uniquely created and stored safely. This study was approved by Partners Institutional Review Board (IRB) #2018P002762.

Only non-dermatologic patient history and physical exam notes were included to mimic real-world settings. Photographs were captured primarily by Dermatology Residents from the Harvard Combined Dermatology Residency. Camera use was heterogenous and included Sony NEX5N 12MP and 5MP iPad Mini. Images were obtained both by using the original digital images and screengrabs from the electronic medical record. Study data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at Partners.(18, 19)

The packaged cases were sent to 27 experienced dermatology hospitalists in order of response to request for participation at various academic institutions across the U.S. Each remote teledermatologist (TD) received six to seven cases within a secure REDCap survey (Supplemental Figure 1). Each clinical case was evaluated by 4-5 unique TDs.

The surveys included the option to list a primary diagnosis as well as a maximum of three differential diagnoses. The workup and management plans offered were as follows: (1) biopsy, (2) topical therapy, (3) systemic/oral therapy, (4) microbiology, (5) labs, (6) transfer to the burn unit, if not already there, (6) recommend continued patient monitoring as an inpatient, and (7) recommend follow-up as outpatient for dermatologic condition. Once the TD selected a treatment plan, s/he was prompted for free-text details. Both the correct mode and type of therapy was assessed. If the selected treatment differed between the PD and the TD but both options were within the accepted standard of care for that disease, these treatments were

considered concordant. This was to minimize the effect of stylistic practice differences in grading appropriateness.

The follow-up plan options were: (1) sign-off and no need for future follow-up either inpatient or outpatient, (2) outpatient follow-up, no need for additional inpatient dermatology evaluations ("sign off"), (3) no need to see the patient tomorrow, but evaluate if the primary team requests and ensure outpatient follow-up planned, and (4) see the patient tomorrow and follow closely. TDs rated their degree of comfort in managing the case as a dermatologist, as well as the quality of each image.

Outcomes measured were concordance between the PD and the TDs for the following: primary diagnosis, primary diagnosis plus differential diagnosis, decision to biopsy, laboratory work-up, imaging, treatment, and follow-up plan. Primary outcomes were defined as primary plus differential diagnostic concordance as well as management plan concordance, the rational of which was to assess whether teledermatology could result in an appropriate work-up and management leading to an effective outcome for the patient. Secondary outcomes were primary diagnostic concordance alone, as well as concordance in work-up.

Primary diagnostic concordance was defined as agreement between the primary diagnosis provided by the PD and the TD. Primary diagnostic plus differential diagnostic concordance was defined as the PD's diagnosis being among the differential diagnosis of the TDs in cases when the primary diagnosis was discordant. The diagnoses themselves, and not diagnostic family, were used in calculating diagnostic concordance.

Statistical Analysis

We calculated the prevalence-adjusted bias-adjusted kappa (20) to quantify the concordance between a) the TDs' and PD's primary diagnosis, b) TDs' primary diagnosis plus differential

diagnosis and PD's primary diagnosis, and c) TDs' and PD's management plan (separately for each of the five domains: biopsy, work-up, imaging, treatment, and follow-up). The following criteria were used to assess significance: values ≤ 0 as indicating no agreement, 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement.(21) We evaluated the associations of the calculated concordance a) and b) with TDs' years of experience and the reported photo quality rating, and the associations of the calculated concordance c) with photo quality using the Pearson correlation coefficient. We also evaluated the associations of TDs' level of comfort managing patients (with photos and story alone) with photo quality and TDs' years of experience using the Wilcoxon rank sum test. All were conducted using R version 3.6.1 (https://www.r-project.org/).

RESULTS

Table 1 depicts the characteristics of the patients included in the study surveys. The mean age was 54.1 years (standard deviation (SD) 23.7), 43.9% were female, 75.6% identified as Caucasian, and 68.3% as Non-Hispanic or Latino. The final diagnoses are provided that were used to evaluate diagnostic concordance. Diagnoses fell under a diverse set of diagnostic families, consisting of hypersensitivity reactions (29.3%), vascular (19.5%), infectious (17.1%), inflammatory (17.1%), neoplastic (7.3%), iatrogenic (4.9%) and traumatic (4.9%).

The TDs were 40.7% female and practiced in diverse academic institutions from all geographic regions of the United States. The mean number of years' experience of each of the TDs was 7.0 (SD 1.2) (Table 2). Out of all cases, 45.1% of TDs felt comfortable managing the case as a teledermatologist. The mean number of differential diagnoses per TD per individual case was 2.6 (SD 0.4).

There was fair concordance between PD and TD primary diagnosis alone (median concordance 66.7%, interquartile range (IQR) 57.1% to 78.6%; median kappa=0.33, interquartile range (IQR) 0.14 to 0.57), with substantial agreement between PD and TD primary plus differential diagnosis (median concordance 91.7%, IQR 85.7% to 92.9%; median kappa=0.83, IQR 0.71 to 0.86). There was substantial agreement in pursuing additional laboratory work-up (median concordance 85.7%, IQR 85.7% to 92.9%; median kappa=0.67, IQR 0.43 to 0.79), and almost perfect agreement in imaging decisions (median concordance 100%, IQR 50.0% to 100.0%; kappa=1.0, IQR, 0.0-1.0). There was moderate agreement in the decision to biopsy (median concordance 71.4%, IQR 53.6% to 85.7%; median kappa=0.43, IQR 0.07 to 0.71). There was almost perfect agreement in treatment plans (median concordance 100%, IQR 85.7% to 100.0%; median kappa=1.0, IQR 0.67 to 1.0). There was no agreement in the follow-up plan (median concordance 50.0%, IQR 42.9% to 66.7%; median kappa=0.0, IQR -0.14 to 0.14). Figure 2 is a pair of histograms depicting the distribution of kappa values for agreement between the TDs' and the PD's primary diagnosis (Figure 2A), and primary plus differential diagnosis (Figure 2B). There was no association between experience of the TD and primary plus differential diagnostic concordance (correlation=-0.27; 95% confidence interval (CI) -0.59 to 0.12, scatterplot in Supplemental Figure 2, corresponding Supplemental Table 1) or primary diagnostic concordance (correlation=-0.27; 95% CI, -0.59 to 0.12). There was also no association between years' experience of the TD and decision to pursue laboratory evaluation (correlation=-0.19; 95% CI, -0.53 to 0.21), biopsy (correlation=-0.32; 95% CI, -0.62 to 0.07), imaging (correlation=-0.19; 95% CI, -0.53 to 0.21), treatment decisions (correlation=-0.18; 95% CI, -0.53 to 0.21), and follow-up planning (correlation=-0.06; 95% CI, -0.33 to 0.43).

There was no association between either raw photo quality and the primary plus differential diagnosis (correlation=0.008; 95% CI, -0.18-0.19), or primary diagnostic concordance alone (correlation=-0.07; 95% CI, -0.12-0.25). The Wilcoxon rank sum test of the TDs' comfort with managing the case and years of experience indicated that TDs with fewer years of experience were more likely to feel comfortable managing the patients as a teledermatologist (p=0.04).

DISCUSSION

This study illustrates that store-and-forward teledermatology may be reliable in the academic inpatient setting, with strong agreement between PD and TD for diagnosis, work-up, and management.

The high concordance of primary plus differential diagnosis is in-line with prior outpatient literature,(8, 22) with studies demonstrating diagnostic concordance ranging from 41% to 100% for store-and-forward cases.(2) This finding builds upon limited studies evaluating the use of teledermatology in the inpatient setting.(12, 23, 24) As with prior study,(2) diagnostic concordance improved when the differential diagnosis was taken into account.

The decision by TDs to pursue work-up in this study was highly concordant, with substantial agreement in the laboratory work-up desired. However, there was only moderate agreement in the decision to biopsy, which is in contrast with a prior inpatient teledermatology study finding a >95% concordance in assessing need for biopsy.(12) This may be due to stylistic practice differences or individual comfort level.

The treatment plans offered by the TDs were highly concordant with those of the PD, suggesting that the outcomes of each patient may have been the same if managed by teledermatology, even in cases where the primary diagnosis differed. This may be due to the high concordance of primary plus differential diagnosis, leading to treatment plans applicable to multiple diagnoses.

The baseline inter-dermatologist variability that occurs even with face-to-face consultations must also be taken into consideration, as a previous study of face-to-face, clinic-based dermatologists has found diagnostic testing to be 85% concordant, medical-based therapy to be 85% concordant, and clinic-based therapy 77% concordant, respectively.(22) Thus, some degree of discordance may be expected.

The lack of concordance between TDs and the PD for follow-up plans suggests that in-person evaluation may be needed prior to disposition planning. Stylistic differences also likely played a role. Patient-specific factors may go into disposition planning, such as access to resources and health literacy, which may contribute to the discordance between the PD and the TDs. Further study of follow-up planning is needed to elucidate whether teledermatology may be reliable for this use.

Photo quality was not associated with primary diagnostic concordance or primary plus differential diagnostic concordance. This suggests that even in cases in which image quality is suboptimal, the reliability of teledermatology may not be impacted. However, while the authors utilized images from heterogeneous sources, many photos utilized in the study surveys met the minimum standards recommended for teledermatology.(25) Additionally, assessment of image quality was not broken down into detailed components, such as lighting, focus, or capture of clinically-relevant information. Photo quality and training in obtaining photos may be needed to ensure good capture of the relevant areas when implementing teledermatology, as the study photos were captured by dermatology resident physicians.

There was no association between experience of the teledermatologist and diagnostic concordance, illustrating the generalizability of teledermatology across all ages of practicing dermatologists.

There appeared to be a disconnect between concordance and the TDs' level of comfort in managing each case as a teledermatologist. The TDs considered themselves comfortable less than half of the time; however, their survey responses often aligned with the PD. This may be in part due to the novelty of teledermatology. The TDs with fewer years of experience were more likely to feel comfortable managing the case, aligning with prior literature,(26) reflecting an opportunity to utilize teledermatology even in novice practice settings. Similarly, teledermatology exposure in residency may correlate with comfort of use,(27) suggesting that early incorporation of teledermatology in training may facilitate its implementation.

One of the greatest strengths of this study is the large sample size of TDs, mimicking the heterogeneity of applying teledermatology to real-life practice settings. The distribution of diagnoses included in this study reflects that of common dermatology consultations.(13) Limitations of this study include its single-center nature and the fact that dermatology residents captured the clinical photos. The dermatology residents may have had a more thorough understanding of how to obtain a high-quality dermatology photo than non-dermatology staff, who would be submitting the teledermatology consult in real-life. Training of non-dermatology staff in obtaining high-quality images may be needed. On the other hand, camera technology has likely improved today and may lead to heightened quality of photos in today's use of teledermatology. Further study is needed to determine best practices for implementing an inpatient teledermatology program.

In conclusion, teledermatology may be effective for managing dermatologic disease in the inpatient setting and leads to highly concordant diagnostic, work-up, and management decisions when performed by experienced inpatient dermatologists. This may represent a novel and effective option for community hospitals and may be particularly applicable during times of

349 concern for spread of infectious disease, such as during the 2019-2020 outbreak of the severe
350 acute respiratory syndrome coronavirus 2 (SARS-CoV-2).
351

352 **Table 1.** Demographic characteristics of patients included in this study.

Patient characteristic	**Total (n=41)**
Age in years, mean (SD)	54.1 (23.7)
Sex, n (%)	
Female	18 (43.9)
Race, n (%)	
Asian	2 (4.9)
Black or African American	4 (9.8)
Caucasian	31 (75.6)
Unknown	4 (9.8)
Ethnicity	
Hispanic or Latino	0 (0.0)
Not Hispanic or Latino	28 (68.3)
Unknown	13 (31.7)
Dermatologic consultation characteristics	
Chronology of skin findings, median (IQR) (days)	4.0 (2.0-14.0)
Medications, mean (SD)	7.0 (3.7)
Final diagnostic categories	
Hypersensitivity	12 (29.3)
Contact dermatitis (4)	
Drug hypersensitivity (6)	
Erythema nodosum	
Urticaria	
Vascular	8 (19.5)
Calciphylaxis	
Henoch-Schonlein purpura	
Leukocytoclastic vasculitis	
Lipodermatosclerosis	
Small vessel vasculitis	
Stasis dermatitis (3)	
Infectious	7 (17.1)
Atypical mycobacterial infection	
Bullous impetigo	
Eczema herpeticum	
Herpes simplex virus	
Erythema chronicum migrans (2)	
Varicella zoster virus	
Inflammatory	7 (17.1)
Atopic dermatitis	
Gout	

Granulomatous disease Hiradenitis suppurativa Miliaria rubra Pyoderma gangrenosum (2)	
Neoplastic	3 (7.3)
Carcinoma erysipeloides Kaposi sarcoma Nevus lipomatosus	
Iatrogenic	2 (4.9)
Steroid acne Warfarin skin necrosis	
Traumatic	2 (4.9)
Bateman's purpura Neurotic excoriations	

Table 2. Characteristics of the surveyed teledermatologists.

Characteristic	**Total (n=27)**
Sex, n(%)	
Female	11 (40.7)
Geographic distribution	
Northeast	13 (48.2)
Midwest	5 (18.5)
West	5 (18.5)
Southeast	3 (11.1)
Southwest	1 (3.7)
Years of experience, mean (SD)	7.0 (1.2)

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FIGURE LEGENDS

Figure 1. Selection criteria for cases to include in study.

Figure 2. Distribution of Kappa values for agreement between the teledermatologists' and the primary dermatologist's (A) primary diagnosis and (B) primary plus differential diagnosis.

SUPPLEMENTS

Supplemental Figure 1. Sample case within a survey set provided to the teledermatologists. The original diagnosis provided by the primary dermatologist was an atypical mycobacterial infection.

Supplemental Figure 2. Scatterplot of the correlation between the teledermatologists' (TDs') primary plus differential diagnosis and the primary dermatologist's (PD's) primary diagnosis. Each point represents a teledermatologist (TD), color-coded by which survey set the TD participated in. The absence of clustering of points by color and the wide variation in TDs' years of experience indicate that TDs' years of experience exhibit robust nonassociation with the concordance between the TD's primary plus differential diagnosis and the primary dermatologist (PD)'s primary diagnosis.

Supplemental Table 1. Tabular representation of the years' experience of the teledermatologists (TDs) with corresponding kappa values for primary and primary plus differential diagnostic concordance.

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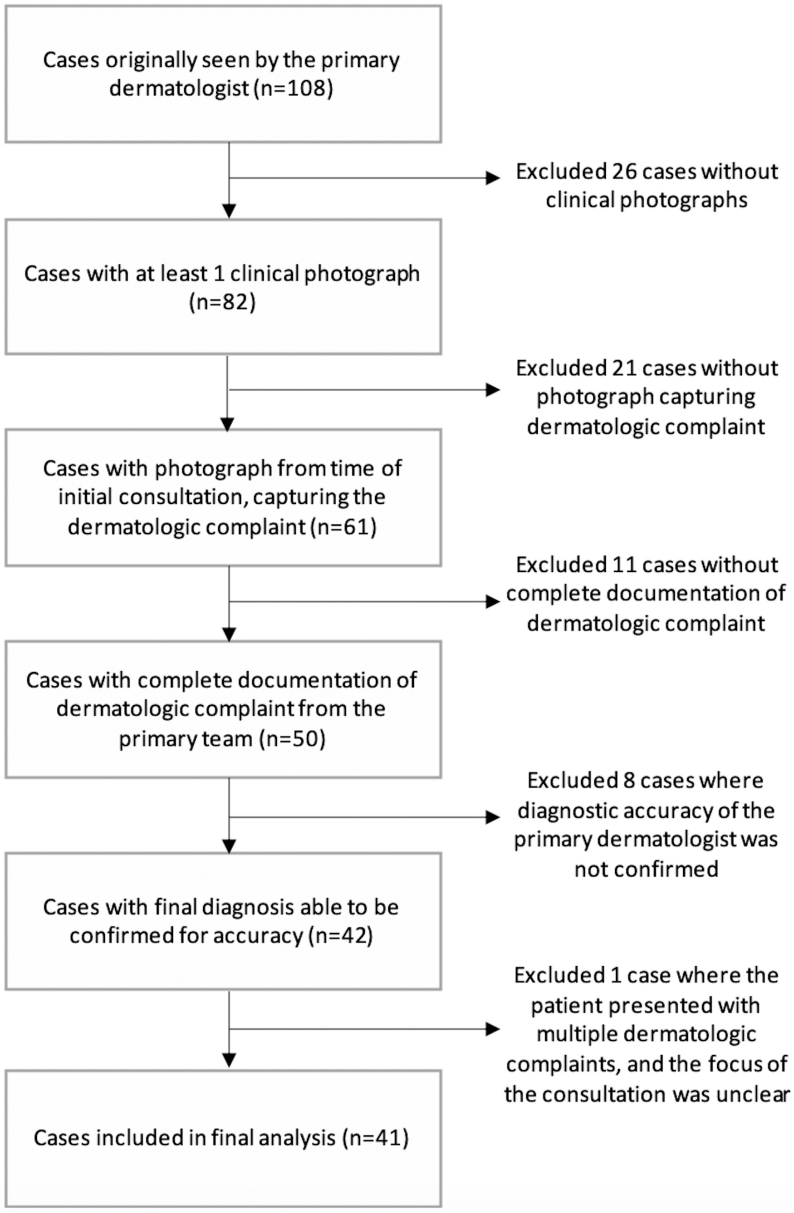
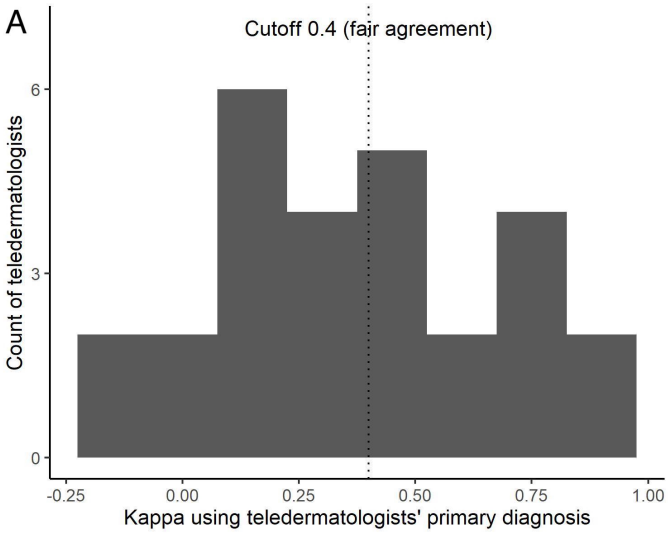
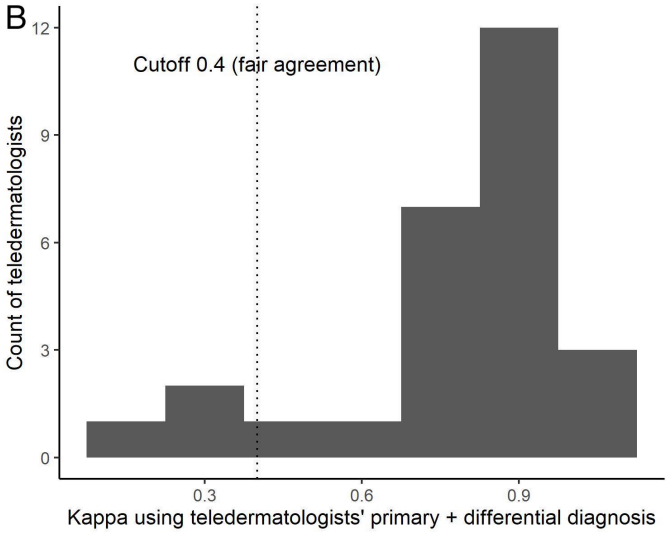

Cases originally seen by the primary dermatologist (n=108)
Excluded 26 cases without clinical photographs
Cases with at least 1 clinical photograph (n=82)
Excluded 21 cases without photograph capturing dermatologic complaint
Cases with photograph from time of initial consultation, capturing the dermatologic complaint (n=61)
Excluded 11 cases without complete documentation of dermatologic complaint
Cases with complete documentation of dermatologic complaint from the primary team (n=50)
Excluded 8 cases where diagnostic accuracy of the primary dermatologist was not confirmed
Cases with final diagnosis able to be confirmed for accuracy (n=42)
Excluded 1 case where the patient presented with multiple dermatologic complaints, and the focus of the consultation was unclear
Cases included in final analysis (n=41)





Capsule summary:

- Inpatient access to dermatologists is limited, highlighting an opportunity to utilize teledermatology within the inpatient setting.
-Teledermatology in the inpatient setting may be a clinically acceptable option for diagnosis, evaluation, and management. This may represent a novel and effective option for hospitals.