Reliability and accuracy of smartphones for paediatric infectious disease consultations for children with rash in the paediatric emergency department

İlker Devrim1*, Mine Düzgöl1, Ahu Kara1, İlknur Çağlar1, Fatma Devrim2, Nuri Bayram1 and Hurşit Apa3

Abstract
Objective: Smartphones and associated messaging applications have become the most common means of communication among health care workers and the general population. The aim of this study was to evaluate the reliability and accuracy of smartphones for the diagnosis of rash in children admitted to emergency departments during the night shift.

Methods: The images of the children who were admitted to the paediatric emergency department with rash were included in this study, and at least two images taken with smartphones by residents or paediatric infectious disease fellows were re-directed to the chief consultant of the Paediatric-Infectious Department via smartphone. Initial diagnosis by the consultant was recorded, and the patient’s physical examination was performed by another clinician on the first working day; diagnostic tests were planned by this clinician. The definitive diagnosis was recorded and compared with the initial diagnosis.

Results: Among the 194 patients, the most common final diagnoses were chickenpox (varicella-zoster infections) in 33 patients (17.0%) and skin infections (including impetigo, eczema, erysipelas and cellulitis) in 33 patients (17.0%). The initial diagnosis, which was performed via WhatsApp on a smartphone, was identical to the final diagnosis in 96.3% of the cases. Incompatible initial diagnoses included 4 measles cases, 1 staphylococcal scalded skin syndrome case, 1 cutaneous leishmaniasis case and 1 petechial rash case.

Conclusions: Our study has shown that the use of a smartphone-based instant messaging application for transmitting images of paediatric rash is accurate and useful for diagnosis. However, physical examination and medical history are still the primary methods. Consultation via smartphones in emergency departments for paediatric rashes during nightshifts would help both clinicians and patients.

Background
The use of smartphones and associated messaging applications, including one of the most popular applications, WhatsApp (WhatsApp Inc., Mountain View, Calif, acquired by Facebook Inc.), in medicine has been increasing and has become the most common way of communicating among health care workers [1]. Smartphones are indispensable in today’s world, and current studies, including marketing surveys, have reported that up to 84% of physicians in the United States use smartphones for professional purposes, and 81% of United Kingdom health care professionals use smartphones [2, 3]. As technology develops, improved smartphones with high-resolution cameras and high-speed internet connections with wide coverage make sharing photos and videos via applications easier and faster. One of the successful and most commonly used applications is WhatsApp (WhatsApp Inc., Mountain View, Calif, acquired by Facebook Inc), which has reached 900 million users, 64 billion messages, and 600 million pictures per day [1].

Smartphones have been widely used for educational purposes in residency and fellowship programmes. Residents
The consultant was recorded, and the patient's conducted with the consultant. The initial diagnosis by consultations performed during the night shift, was and basic biochemical tests) obtained during routine ing limited information such as complete blood count features, medical history, and laboratory results (includ-

dinformation, including demographic and epidemiologic
disease fellows. Additiona lly, a phone call with verbal paediatric residents or indirectly through paediatric

WhatsApp instant messaging application by either the smartphone (iPhone 6, Apple Inc., Cupertino, Calif) via

the Pediatric Infectious Disease Department consultant phones by paediatric residents, which were re-directed to

The patients had at least two images taken with smart-

phones by paediatric residents, which were re-directed to

the Pediatric Infectious Disease Department consultant's smartphone (iPhone 6, Apple Inc., Cupertino, Calif) via

WhatsApp instant messaging application by either the paediatric residents or indirectly through paediatric
disease fellows. Additionally, a phone call with verbal information, including demographic and epidemiologic features, medical history, and laboratory results (including limited information such as complete blood count and basic biochemical tests) obtained during routine consultations performed during the night shift, was conducted with the consultant. The initial diagnosis by the consultant was recorded, and the patient's physical examination was performed by another clinician unaware of the diagnosis by the consulting clinician within the following 12 h of messaging. The images of the patients whose physical examination was not performed within 12 h were not included in the study. The second diagnosis of the patients after physical examination was recorded, and the definitive diagnosis after the diagnostic tests, including serological and molecular diagnostic tests, was recorded (Fig. 1).

Data were analysed with SPSS, version 19.0 (IBM company, US). The descriptive analysis was performed using frequencies and quartiles. Cohen's kappa was used to determine if there was agreement between the two clinicians' diagnoses. The study was approved by the local ethical committee of the institution. Written informed consent was obtained from participants and the parents, and assurance was given that original images would not be used anywhere else by the investigators.

Results
A total of 249 patients were enrolled in the study: 19 patients who had only one suboptimal image and 16 pa-

ents who did not come for treatment or were lost to follow up were excluded. Twenty patients who had come for treatment 12 h past onset were also excluded. The remaining 194 images were included in the study. Among the 194 patients, 58 (29.9%) were females and 136 (70.1%) were males. The mean age was 58.1 ± 45.0 months (ranging from 23 days to 16 years).

Among the 194 patients, the most common final diagnoses were chickenpox (varicella-zoster infections) in 33 patients (17.0%) and skin infections (including impetigo, eczema, erysipelas and cellulitis) in 33 patients (17.0%), followed by shingles (herpes zoster infections) in 13 patients (6.7%), insect bite in 9 patients (4.6%) and herpes-simplex infections in 7 patients (3.6%). There are 10 patients (5.1%) with “non-specific” exanthems who had no definite diagnosis after the diagnostic tests were done and reviewed in the miscellaneous diagnosis part.

The final diagnoses of the patients are reviewed in Table 1. The initial diagnosis, which was performed via WhatsApp on the smartphone, showed 96.3% compatibility with the final diagnosis. Cohen's kappa was used to determine if there was agreement between the two clinicians' diagnoses of 194 children with rashes. There was almost perfect agreement between two clinicians' diagnoses of the children, K = 0.944, p < 0.005.

Incompatible preliminary diagnoses included 4 measles cases, 1 staphylococcal scalded skin syndrome case, 1 cutaneous leishmaniasis case and 1 petechial rash case. The suspected measles cases were in patients 5 to 36 months of age, and further serological and molecular diagnostic methods, including polymerase chain reaction, excluded the diagnosis. In three of the four patients, no aetiology of the rash was determined. The initial diagnosis of one patient whose face was severely erythematous and oedematous with crust and purulent lesions associated with low-grade fever was staphylococcal scalded skin syndrome; the child was hospitalized in the Paediatric Infectious Disease Ward, however, a re-evaluation of the child's medical history and physical examination revealed that the child had a sunburn injury due to excessive sun exposure on the beach while the family left him sleeping.
The final diagnosis of one patient with diffuse petechia localized on her right leg was diagnosed as a jellyfish sting from her medical history. The last patient was a 4-year-old Syrian patient who had an ulcerated lesion on her forehead; the initial diagnosis was cutaneous leishmaniasis. However, the histopathological and bacteriological investigations revealed a diagnosis of lupus vulgaris.

**Discussion**

In the medical field of paediatrics, smartphones are widely used. The spectrum of use of smartphones is wide and includes assessing neonatal jaundice, using checklists for paediatric emergency guidelines, managing diarrhoeal diseases in resource-limited settings and utilizing smartphone-integrated electrocardiograms, in addition to educational purposes for paediatric trainees [4–8]. In this study, we evaluated the clinical diagnostic accuracy of images of paediatric patients sent via the WhatsApp smartphone application by consultants from the paediatric ED during the night shift.

The compatibility rate of diagnoses via WhatsApp in this study was 96.3%. To our knowledge, this is the first study focusing on the utility of smartphones for the consultation and diagnosis of paediatric rash in the paediatric ED. Hubiche et al. evaluated adult and paediatric patients who had taken photos of their skin lesions with their smartphone during outpatient visits [9]. In this study, a total of 162 patients were included, of which paediatric patients formed the majority of the patients, and photography of the lesions via smartphones was found to be useful, especially in patients without skin lesions at the time of the clinical visit [9]. In this study, the photographs of the lesions were taken by the patients using their own smartphones; however, in our study, the photographs were taken by the residents who might be more selective in choosing the best characteristic lesions (if there was more than one lesion) of the patients, which might increase the accuracy.

Since the last decade, overcrowding of paediatric EDs has become an important issue, and rash comprises a
considerable amount of ED visits. The rapid differential diagnosis of the rash is very important for the early treatment of patients, such as in cases of meningococcal meningitis, protecting other patients in the emergency room and taking precautions for preventing transmission, such as in the case of measles. In this study, the patients with rash or skin lesions had been diagnosed with a variety of diseases, including infectious and non-infectious diseases, and consultation via smartphone successfully helped the rapid diagnosis during night shifts. However, consultation via smartphones resulted in the misdiagnosis of 4 patients with an incorrect diagnosis of measles. A clinical case definition for measles has been developed for epidemiological purposes; however, due to its nature, measles can be difficult to distinguish from other febrile exanthems, such as rubella, roseola, erythema infectiosum, human herpesvirus 6, Epstein-Barr Virus infection and drug eruptions. Thus, confirmation of the diagnosis by laboratory testing has become routine, and laboratory results had excluded the diagnosis of measles. A possible diagnosis of measles resulted in isolation precautions in these patients, which might be the most reasonable strategy for protecting other patients and health care workers in EDs before the exclusion of measles.

In our study, 5% of the patients etiological diagnoses could not be found after evaluation of morphology and laboratory investigations, and were defined as “non-specific exanthema”. In one study from Italy including 112 adult and child patients, 36 (32%) of the patients had no specific diagnosis after investigations, supporting an older study including only children reporting 35% of the children remained undiagnosed [10, 11]. The difference in the rates of undiagnosed “non-specific” exanthems can change according to the geographical features, seasonal changes, vaccination programs, vaccination coverage and the availability of the diagnostic tests. In our study, most of the incompatible preliminary diagnoses were diagnosed as “non-specific” exanthems after investigations. In the clinical settings in which “non-specific” exanthems are more common, it would not be wrong to suggest that the agreement level between clinician’s diagnoses would not be as high as in our study.

One of the important issues with smartphone-based instant messaging application for transmitting images is the protection of personal data. According to the firm’s own website, WhatsApp’s end-to-end encryption provides unique lock and key for recipients and message sender [12], however the debate about the concerns of security of patients confidentiality are increasing. Finally, National Health service of England had advised officially that WhatsApp should never be used for the sending of information in the professional healthcare environment [13]. Moreover there are also legal regulations within General Data Protection Regulation in the European Union [14]. In our clinical practice, this kind of application is fast and useful, and still used in our country extensively, enabling fast communications between doctors. However new security standards for WhatsApp or new applications for health professionals for sharing data should be developed [15]. In our study, no personal data such as name, surname and identifying features were shared via WhatsApp, and personal data was shared via phone call between health professionals.

There are some limitations to this study. The data were retrospectively collected from the medical consultation forms and no additional information about the quality of the images, the technical features of the cameras of the

| Causes                                                      | Number of patients (%) |
|-------------------------------------------------------------|------------------------|
| **Herpesviridae infections**                                |                        |
| Chickenpox                                                 | 33                     |
| Zona zoster                                                 | 13                     |
| Roseola infantum                                            | 5                      |
| Herpes simplex virus infections                             | 13                     |
| **Other viral infections**                                  |                        |
| Epstein-Barr-Virus                                          | 3                      |
| Erythema Infectiosum                                       | 6                      |
| Rubella                                                     | 1                      |
| Measles                                                     | 1                      |
| Hand-foot-and-mouth disease                                 | 9                      |
| **Superficial skin infections and cellulitis**              |                        |
| Impetigo and pyodermitis                                   | 17                     |
| Scarlet fever                                               | 6                      |
| Cellulitis and erysipelas                                   | 15                     |
| Paronychia                                                  | 3                      |
| Kerion                                                      | 4                      |
| **Parasitosis and fungal infections**                       |                        |
| Scabies                                                     | 5                      |
| Cutaneous leishmanias                                       | 3                      |
| **Necrotizing cellulitis and subcutaneous tissue infection**|                        |
| Erythema multiforme major                                   | 10                     |
| Steven-Johnson Syndrome/ Toxic epidermal necrolysis        | 4                      |
| Purpura fulminans                                           | 2                      |
| **Non-infectious diseases**                                 |                        |
| Allergic reactions                                          | 18                     |
| Insect bite                                                 | 10                     |
| Erythema nodosum                                            | 1                      |
| Miscellaneous*                                              | 12                     |
| **TOTAL**                                                   | **194**                |

*Includes 1 sun burn, 1 Lupus vulgaris and 10 “non-specific” exanthems whose etiology was not classified despite laboratory tests.
smartphone or the smart phone brand was available. Characteristics of skin lesions or rashes might change after photos are taken via smartphone as time passes; however, a maximum of 12 h was set as the maximum time interval between the initial diagnosis to the physical examination by the paediatric infectious disease specialist. To our knowledge, this is the first study on the utility of WhatsApp via smartphones for the differential diagnosis of rash in paediatric EDs.

Conclusions
Our study has shown that the use of a smartphone-based instant messaging application for transmitting images of paediatric rash is accurate and useful for differential diagnoses. However, physical examination and medical history taking are still the primary methods of evaluation of paediatric rash. Due to its advantages, such as its speed and reduction of wait times, instant messaging services and smartphones might be one of the complementary components of paediatric infectious disease consultations in EDs, especially during night shifts.

Abbreviation
ED: Emergency department

Acknowledgements
Not applicable

Funding
No funding was secured for this study.

Availability of data and materials
The datasets generated and/or analysed during the current study are not publicly available due to the hospital policy but are available from the corresponding author on reasonable request.

Authors’ contributions
ID conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. MD, IC, AK, FD designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and critically reviewed the manuscript. HA coordinated and supervised data collection and critically reviewed the manuscript for important intellectual content. HA coordinated and supervised data collection and critically reviewed the manuscript. MD, IC, AK, FD designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and critically reviewed the manuscript. HA coordinated and supervised data collection and critically reviewed the manuscript for important intellectual content. All authors read and approved the final manuscript.

Ethics approval and consent to participate
The study was approved by the local ethical committee of Behcet Uz Children’s Hospital (reference number: 2018/ 236). The informed consent was taken from the family and children.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details
1Department of Pediatric Infectious Diseases, Dr. Behçet Uz Children’s Hospital, Izmir, Turkey. 2Department of Pediatric Emergency Department, Dr. Behçet Uz Children’s Hospital, Izmir, Turkey.

Received: 12 December 2018 Accepted: 22 January 2019
Published online: 31 January 2019

References
1. Statistic and Facts about mobile messenger app usage. STATISTA Web Site. September 2017. Available at: http://www.statista.com/topics/1523/mobile-messenger-apps/. Accessed 30 Dec 2018.
2. Kantar Media’s Sources & Interactions Study, September 2016: Medical/Surgical Edition. “Professional Usage of Smartphones by Doctors” available at https://www.kantarmedia.com/us/thinking-and-resources/blog/professional-usage-of-smartphones-by-doctors-2016. Accessed 30 Dec 2018.
3. Ozdalga E, Ozdalga A, Ahuja N. The smartphone in medicine: a review of current and potential use among physicians and students. J Med Internet Res. 2012;14:e128.
4. Jyothi S, Halton F, Goodyear H. Use of smartphone apps by paediatric trainees. Br J Hosp Med (Lond). 2015;76(8):475–7. https://doi.org/10.12968/hmed.2015.76.8.475.
5. Taylor JA, Stout J, de Grief L et al. Use of a Smartphone App to Assess Neonatal Jaundice. Pediatrics. 2017;140(3). pii: e20170312. doi: https://doi.org/10.1542/peds.2017-0312.
6. Galvez J, Lockman J, Schleeflein L et al. Interactive pediatric emergency checklists to the palm of your hand - How the Pedi Cris App traveled around the world. Paediatr Anaesth. 2017;27(8):835–40. https://doi.org/10.1111/pa.13173 Epub 2017 Jun 7.
7. Haque F, Ball RL, Khatan S et al. Evaluation of a Smartphone Decision-Support Tool for Diarrheal Disease Management in a Resource-Limited Setting. PLoS Negl Trop Dis. 2017;11(1):e0005290. https://doi.org/10.1371/journal.pntd.0005290.eCollection 2017 Jan.
8. Nguyen HH, Van Hare G, Rudokas M et al. SPEAR Trial: Smartphone Pediatric Electrocardiogram Trial. PLoS One. 2015;10(8):e0136256. https://doi.org/10.1371/journal.pone.0136256.eCollection 2015.
9. Hubiche T, Valério L, Boralevi F et al. Research Group of the French Society of Pediatric Dermatology Groupe de Recherche de la Société Française de Dermatologie Pédiatrique. Visualization of Patients’ Skin Lesions on Their Smartphones: A New Step During Dermatology Visits. JAMA Dermatol. 2016;152(1):95–7. https://doi.org/10.1001/jamadermatol.2015.2977.
10. Drago F, Rampini E, Rebova A. Atypical exanthems: morphology and laboratory investigations may lead to an aetiological diagnosis in about 70% of cases. Br J Dermatol. 2002;147(2):253–60.
11. Goodyear HM, Ladier PW, Price DH et al. Acute infectious erythemas in children: a clinico-microbiological study. Br J Dermatol. 1991;124(5):433–8.
12. WhatsApp Security. https://www.whatsapp.com/security/. Accessed 30 December 2018.
13. National Health Service. Revisions due EU data protection laws. England Information Governance Bulletin2015;21:1–5. http://webarchive.nationalarchives.gov.uk/20160606050915/https://www.england.nhs.uk/wp-content/uploads/2015/01/lg-bull-21.pdf. Accessed 30 Dec 2018.
14. General Data Protection Regulation. https://gdpr-info.eu. Accessed 1 Jan 2019.
15. Thomas K. Wanted: a WhatsApp alternative for clinicians. BMJ. 2018;360:k622. https://doi.org/10.1136/bmj.k622.