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REVIEW ARTICLE

Teledermatology: A Review and Update

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Abstract Telemedicine is slowly transforming the way in which healthcare is delivered and has the potential to improve access to subspecialty expertise, reduce healthcare costs, and improve the overall quality of care. While many subspecialty fields within medicine today have either experimented with or begun to implement telemedicine platforms to enable remote consultation and care, dermatology is particularly suited for this care system as skin disorders are uniquely visible to the human eye. Through teledermatology, diagnostic images of skin disorders with accompanying clinical histories can be remotely reviewed by teledermatologists by any number of modalities, such as photographic clinical images or live video teleconferencing. Diagnoses and treatment recommendations can then be rendered and implemented remotely. The evidence to date supports both its diagnostic and treatment accuracy and its cost effectiveness. Administrative, regulatory, privacy, and reimbursement policies surrounding this dynamic field continue to evolve. In this review, we examine the history, evidence, and administrative landscape surrounding teledermatology and discuss current practice guidelines and ongoing controversies.

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Key Points

The three types of teledermatology care delivery platforms are synchronous, asynchronous, and hybrid.

The vast majority of research studies have found teledermatologic skin care to be comparable to conventional face-to-face care.

Teledermatology research data support its cost effectiveness and ability to decrease the need for in-person evaluations.

Practice guidelines for teledermatology have been developed by the American Telemedicine Association and American Academy of Dermatology.

1 History of Teledermatology

The earliest forms of telemedicine were described as far back as the eighteenth and nineteenth centuries, during which time sick individuals would pen medical histories and send letters detailing their symptoms by courier to physicians, who would reply with a diagnosis, treatment plan, and written prescription [1]. This historical form of "pre-electronic" telemedicine enabled remote consultation between patient and physician and would lay the foundations for modern-day telemedicine. Telemedicine has since evolved closely alongside advancements in audiovisual and telecommunications technology. For instance, the invention of the telegraph in the mid-1800s enabled Willem

Einthoven, a Dutch physician and inventor of the electrocardiogram (ECG), to transmit ECGs from the hospital to an off-site laboratory [2]. The first "tele-stethoscope" was described in 1910; it enabled auscultation via stethoscope and telephone networks [3].

The first remote evaluation of medical images dates back to 1948, when radiologic images were reportedly first transferred by telephone, laying the groundwork for one of the earliest teleradiology platforms [4]. The remote assessment of medical images continued to evolve in the 1960s and 1970s, with specialties such as radiology, pathology, and, increasingly, dermatology, experimenting with live visual modalities such as broadcast television [5, 6]. However, the image quality with most live visual modalities at that time paled in comparison with that of still photographic images. However, the development of digital compressors, the internet, and email in the 1990s enabled a new form of telemedicine by providing an "information highway" upon which high-resolution images could be shared alongside clinical histories between providers and experts worldwide through a novel store-and-forward (SAF) technique.

These more recent advancements in technology and telemedicine laid the groundwork for modern-day teledermatology, which was developed, in part, out of the need to help provide "good medicine in bad places" [7]. Such practices were pioneered by the US Department of Defense (DoD) in 1992 during the 'Operation Restore Hope' humanitarian relief mission in Somalia, where a digital camera, laptop computer, and portable satellite transceiver enabled 74 digital consultations over the course of a year [8]. The DoD pioneered both live video teleconferencing (VTC) as well as SAF techniques and was among the first to report the superiority of SAF techniques [7]. Since this time, teledermatology has been a key component of the DoD's telemedical services, with dermatologic conditions accounting for up to three-quarters of outpatient visits in combat zones and skin complaints constituting just under half of military telemedicine consultations [8]. In addition to expanding access to dermatologic expertise in combat zones, teledermatology has also historically helped extend access in remote rural areas in the USA. In fact, in the first publication to apply the term "teledermatology" in the English medical literature, Perednia and Brown [9] described the launch of a teledermatology initiative at the Oregon Health and Sciences University to enable remote diagnostic and treatment recommendations for skin conditions in remote rural areas lacking such dermatologic expertise.

More recent advancements in the mobile and digital communications technologies of the new millennium have empowered a new generation of teledermatology applications and ignited interest in the field of teledermatology from both academia and industry. The literature on teledermatology has grown steadily since the late 1990s and into the 2000s, with Brewer et al. [10] reporting a total of 229 dermatology-related mobile applications by 2013, and this number is expected to grow [11]. Many parts of the world now have easier access to wireless networks than to clean water. To this effect, the World Bank estimated that, in 2015, there were 98.3 mobile cellular subscriptions per 100 people worldwide [12]. As mobile phones and their applications become progressively more accessible and powerful, the mobile teledermatology application market continues to thrive, to drive continued research and innovation, and to expand access to dermatologic expertise and care.

2 Definitions

The three main teledermatology care delivery platforms are synchronous (i.e. live VTC; real-time teledermatology), asynchronous (i.e. SAF), and hybrid (i.e. mixed, having features of both synchronous and asynchronous forms). Synchronous teledermatology typically employs live video conferencing between the patient and the teledermatologist. While the general consensus is that the image quality of transmitted video is inferior to that of captured images, live interaction enables the clinician to clarify aspects of the history and teledermatologic examination and provide direct patient education and treatment instructions. However, this modality is limited by the bandwidth required for transmission of live video and also limits practice across time zones.

Asynchronous teledermatology is typified by the SAF technique, whereby clinical dermatologic images obtained either by the requesting clinician or the patient-consumer are digitally "stored" and "forwarded" to the responding dermatologist, who can review the image and accompanying clinical history. This modality is the most widely used and generally provides higher-resolution dermatologic images than possible through synchronous means and enables an efficient practice that can be performed across time zones. However, this modality is limited by the ability of the teledermatologist to obtain additional clinical history while they are evaluating the case, which would require an additional point of contact with the requesting patient-consumer or consulting clinician and potentially beget inefficiencies.

Finally, mixed or hybrid teledermatology modalities combine live TVC and SAF clinical images. This technique is among the less commonly utilized, partly because of the significant bandwidth and storage space required and difficulty in practicing across time zones. However, this modality overcomes the limitations of both synchronous and asynchronous techniques by allowing for live patient-consumer interview and evaluation of higher-resolution images.

3 Evidence-Based Teledermatology

3.1 Accuracy and Effectiveness

A rapidly growing body of literature supports the reliability of teledermatology for the diagnosis and treatment of skin disorders compared with the standard live in-person examination [13–27]. While rates of diagnostic accuracy by teledermatology vary from study to study, the vast majority has found rates in the mid to high 70th percentile, comparable to those with conventional face-to-face care [20, 27–30]. Isolated studies have favored the superior diagnostic accuracy of teledermatology [31] and few have demonstrated significantly inferior diagnostic accuracy [32, 33]. Studies have shown simple inter-observer agreement rates between teledermatologic and clinic-based evaluations regarding treatment approaches of between 70 and 90% [20, 22, 25, 27, 34–36]. Even greater inter-observer agreement values (80–90%) and kappa statistics (0.4–0.7) have been reported in comparisons of biopsy or operative recommendations for skin neoplasms evaluated by teledermatology or by conventional face-to-face care [27, 35, 37–41].

Several studies have also directly compared the efficacy of specific teledermatology modalities. In a small-scale randomized controlled trial comparing SAF, hybrid SAF, VTC, and face-to-face modalities, Romero et al. [36] found an 85 and 78% concordance in diagnoses rendered and treatment recommended, respectively, between all teledermatology modalities and face-to-face examination. Of interest, they also noted that case-based factors such as image quality and confidence in diagnosis more heavily influenced diagnostic concordance than did the quality of additional history obtained by live VTC, concluding that the addition of the latter modality was no better than SAF alone [36]. These findings contrast somewhat with the conclusions of Loane et al. [42], who found that the inability to promptly obtain additional clinical information when using SAF techniques ultimately led to more in-person follow-ups than did the live VTC technique. However, the effectiveness of live VTC may be limited by image quality, as suggested by a side-by-side comparison [23] wherein this modality led to significantly fewer definitive diagnoses than did face-to-face consultations.

3.2 Cost, Efficiency, and Quality Considerations

To date, economic analyses comparing the costs of SAF teledermatology with those of conventional care support the cost-saving nature of this modality from both the societal and the healthcare sector's perspective. Van der Heijden et al. [43] conducted a prospective analysis of 37,207 SAF teleconsultations between general practitioners and dermatologists over 3 years in the Netherlands and found that the teleconsultations provided an estimated cost reduction of 18% on behalf of the healthcare organization and prevented 74% of in-person referrals. Unpublished data from a review of 402 physician–physician outpatient teledermatology cases at our institution, the University of Pittsburgh Medical Center, revealed similar results, with consultations to outpatient dermatology clinics decreasing by 65%. Similarly, Morton et al. [44] conducted an observational study of 289 "photo-triage" consultations and found that this SAF-type teledermatology reduced the number of in-person referrals by 72%, reduced wait time to surgery by an average of 16 days, and saved approximately £1.7 per patient. Several other studies reported similar findings; Table 1 summarizes these results [43–52]. Comparative cost analyses of synchronous or live VTC teledermatology modalities compared with conventional care have yielded mixed results regarding the cost effectiveness of this teledermatology modality. While several studies have reported potential cost savings, several have reported greater costs than conventional care. Table 2 provides a summary of economic analyses comparing the costs of live VTC or synchronous teledermatologic modalities versus conventional care [53–60].

Studies to date also support the efficiency and cost effectiveness of SAF teledermatology, particularly when it is used as a triage mechanism in settings where longer distances must be traveled for a face-to-face clinical encounter [61]. Hsiao and Oh [62] found that teledermatology also significantly expedited care by significantly reducing time to consult completion, biopsy, and excision of potential skin cancers at a Veterans Affairs dermatology clinic. New data also suggest that teledermatology can provide significant triage benefit for inpatient dermatologic consultations. Barbieri et al. [41] compared in-person and teledermatology assessment and found 90 and 95% agreement regarding the need for same-day evaluation and biopsy, respectively. In addition, they found that teledermatologists were able to triage 60% of consultations for next-day or later evaluation and 10% to be seen as outpatients, providing potential improvements in practice efficiencies for the department [41]. A randomized study throughout the Department of Veterans Affairs investigated the societal and institutional costs of SAF teledermatology compared with those of conventional dermatology outpatient referral and found teledermatology to be significantly cheaper than conventional outpatient evaluations [45]. Similar findings supporting the cost-saving nature of teledermatology have been reported within the DoD system

Table 1 Economic cost analyses: store-and-forward teledermatology versus conventional care

Study	Perspective	Less expensive modality (SAFTD vs. conventional care)	Difference in cost per consult	Other findings
Whited et al. [52]	HCO	Conventional	$US15[a]	Definitive intervention initiated median of 86 days faster
Eminovic et al. [46]	Societal	Conventional	€33[a]	Equivalent effectiveness
Moreno-Ramirez et al. [75]	Societal	SAFTD	€50	Intervention initiated 76 days faster
Pak et al. [50]	HCO	SAFTD	$US30	Factored in productivity loss
Van der Hiejden et al. [43]	HCO	SAFTD	€35	Prevented 74% of referrals
Ferrandiz et al. [47]	Societal	SAFTD	€122	Expedited surgery by 34 days
Morton et al. [44]	HCO	SAFTD	£2	Expedited surgery by average of 16 days
Datta et al. [45]	HCO	SAFTD	$US30	Comparable time trade-off utility values
	Societal	SAFTD	$US82	
Parsi et al. [51]	Societal	SAFTD	$US261	Similar quality-adjusted life-years
Lim et al. [48]	HCO	SAFTD	$NZ42	Reduced wait time by 75 days

HCO healthcare organization, *NZ* New Zealand, *SAFTD* store-and-forward teledermatology

[a] SAFTD is the more expensive modality

Table 2 Economic cost analyses: live videoteleconferencing teledermatology versus conventional care

Study	Perspective	Less expensive modality (VTCTD vs. conventional care)	Difference in cost per consult	Other findings
Wootton et al. [60]	Societal	Conventional	£84[a]	Similar clinical outcomes
Loane et al. [58]	Societal	Conventional	£99[a]	VTCTD more useful than SAFTD
Lamminen et al. [57]	Societal	Conventional	FM593[a]	VTCTD reduced traveling and hospital costs
Bergmo [54]	HCO	VTCTD	NKr164,295	Results maintained despite changes in cost assumptions
Loane et al. [59]	Societal	VTCTD	$NZ4.47	Randomized controlled trial
Chan et al. [55]	HCO	VTCTD	$HK265	Elderly patients living in institutions
Armstrong et al. [53]	HCO	VTCTD	$US72	Hourly operating costs
Dekio et al. [56]	Societal	VTCTD	¥34,460	Rural setting

FM Finnish markka, *HCO* healthcare organization, *HK* Hong Kong, *NKr* Norwegian krone, *VTCTD* video teleconferencing teledermatology

[a] VTCTD is more expensive modality

[50]. Of relevance, Wootton et al. [63] also found nearly half of SAF teledermatology users completely avoided the need for any travel for their care. The addition of teledermatoscopic images was recently shown to potentially improve the triage accuracy of an internet-based SAF teledermatology platform for skin cancer screening [64].

Direct-to-consumer teledermatology applications and users are also on the rise and have great potential in triaging outpatient dermatologic complaints. However, studies suggest that existing direct-to-consumer teledermatology applications may be lacking in quality. For instance, Resneck et al. [65] found that, in addition to repeatedly missing important diagnoses (i.e. secondary syphilis, polycystic ovary syndrome), relevant adverse effects regarding medications or their use during pregnancy were disclosed in only a minority of simulated teledermatologic encounters. Moreover, their data also indicated that direct-to-consumer teledermatology applications do not offer clinician choice, rarely disclose licensure, occasionally utilize internationally based physicians, and infrequently coordinate care with existing primary care physicians [65].

Table 3 Teledermatologic examination: special considerations. Adapted from McKoy et al. [68]

Clinical scenario/context	Points of consideration
Total body skin examination	Feasible by both synchronous and asynchronous modalities but may not demonstrate sufficient detail
	May require special lighting and/or multiple angles and images for sufficient teledermatologic examination
Hair-bearing skin	Examination of skin bearing dense, thick hair (i.e., scalp) will require proper physical maneuvering or removal of hair as well as adequate lighting to ensure proper examination
Pigmented lesions	Represent a diagnostic challenge teledermatologically and requires higher index of suspicion and lower threshold to refer for in-person examination
	Adjunctive teledermatologic examination modalities, i.e., teledermoscopy, should be incorporated if available [64]
Mucosal lesions	Requires careful attention to lighting and camera exposure to ensure adequate, detailed examination
Skin color	Different backgrounds, lighting conditions, and baseline skin color may alter the color of lesions captured teledermatologically

4 Administration: Legislation, Privacy, and Liability in the USA

The Federation of State Medical Boards has issued a statement addressing so-called internet prescribing and the complex regulatory environment surrounding the practice of telemedicine and teledermatology [66]. In summary, their statement maintains that treatment, including prescriptions, and consultation recommendations made online or electronically are held to the same standards of appropriate traditional (i.e., face-to-face) practice [66]. At present, teledermatology practitioners are subject to existing federal, state, and local regulatory and licensure requirements. According to a 2012 survey by the American Telemedicine Association (ATA) [67], teledermatology programs exist in all 50 states and Puerto Rico. Given the remote nature of teledermatology, practitioners will not infrequently have the opportunity to fulfill teledermatology consultations from patients out of state. To do so, such practitioners must designate the state of principal licensure and identify other states in which a license is required. The state of principal licensure then provides the Interstate Commission with the teledermatologist's eligibility and credential information and grants the appropriate interstate medical licensure. Based on existing legislation, the teledermatologist will ultimately be subject to the jurisdiction of the medical board of the state in which the patient is located [68]. Some states require full licensures, others offer restricted licenses, and some offer licensures by endorsement through reciprocity agreements with neighboring states [69]. Practitioners of teledermatology must also ensure compliance with the Health Insurance Portability and Accountability Act (HIPAA) of 1996 along with its amendments and regulations. For both live-interactive and SAF means of teledermatology, encryption of imaging and written patient data transmission is expected to ensure security of sensitive patient information [68]. In addition, authentication of teledermatology providers through biometrics, passwords, or other personal identifiers is strongly recommended by field experts and governing bodies such as the American Academy of Dermatology (AAD) and the ATA [70, 71]. Finally, teledermatology providers must be aware that liability is incurred in medical practice whether in person or electronically and, thus, should verify that their liability insurance policy covers telemedicine services, including remote care provided across state lines [68, 72].

5 Practice Guidelines

In 2016, the ATA published its updated practice guidelines for teledermatology [68, 72]. In addition to delineating detailed clinical guidelines for the teledermatologic patient encounter and the coordination of his or her care from afar, McKoy and colleagues [68, 72] also delineate technical specifications and recommendations to maximize the quality and ensure the security and privacy of transmitted digital images and/or live video as well as all other patient health information. Furthermore, the ATA guidelines also delineate the limitations and challenges of teledermatology in certain clinical contexts or in examining particular anatomic areas of interest that may require special attention (Table 3).

The AAD also delineated its position on teledermatology in a consensus statement updated in 2016 [70]. While much of its key guidelines mirror those of the ATA, the AAD guidelines also emphasize the importance of patients or referring physicians having a choice of teledermatologists and access to board certification qualifications of the clinician providing the care [65, 70]. Furthermore, the AAD guidelines also emphasize the importance of maintaining the physician–patient relationship despite the teledermatologic means. Their recommendations include that a teledermatologist evaluating a SAF teledermatology case should either have previously seen the patient in person, create such a relationship through synchronous or live face-to-face VTC, or be part of an integrated care delivery system in which the patient is enrolled [70].

6 Controversies and Consumer Safety

As the market for mobile teledermatology platforms continues to grow, the number of mobile applications that utilize automated algorithms to diagnose, triage, or assess the risk of skin lesions also increases. Many such applications are available to download for free or at a low cost. While these applications are marketed as being able to assist non-clinician users to decide whether or not a skin lesion is malignant, such applications are not subject to traditional regulatory oversight of clinical or traditional teledermatologic practice. Moreover, according to an investigative review by Kassianos et al. [73], none had undergone validation studies for diagnostic accuracy or utility. For this reason, such applications have significant potential to harm users who may be falsely and inaccurately reassured about a malignant lesion. In a case-control study investigating the diagnostic accuracy of three automated diagnostic applications said to identify melanoma compared with one evaluated by a board-certified dermatologist, Wolf et al. [74] found that the sensitivities and specificities of the automated applications for detecting cutaneous melanoma versus other benign lesions ranged from 6.8 to 70% and from 39.3–93.7%, respectively. While such automated diagnostic applications have their risks for the consumer, a number of other mobile applications provide sound evidence-based patient education on prevention of ultraviolet radiation exposure as well as self-exam strategies, and others can take and store images of lesions for self-monitoring or review by dermatologist [73].

7 Conclusions

Teledermatology is a leading subspecialty of telemedicine that continues to evolve with advancements in telecommunications and mobile phone technology. The evidence to date supports the accuracy and cost effectiveness of teledermatology and its ability to facilitate and expedite dermatologic care. Continued experimentation with and integration of advanced examination techniques, such as teledermoscopy, with the various teledermatologic care delivery modalities (i.e., synchronous and asynchronous vs. hybrid modalities) will continue to improve the quality of teledermatology-delivered care. Institutional regulations and policies will need to address the complex administrative, legislative, reimbursement, and privacy environment. Nonetheless, teledermatology platforms hold great promise to improve access to high-quality dermatologic care.

Compliance with Ethical Standards

Conflict of interest JJL and JCE have no conflicts of interest that are directly relevant to the content of this manuscript.

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