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Teledermatology: Outcomes and Economic Considerations

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1. Introduction

Teledermatology is defined as the provision of dermatologic care through the use of communications technology (Goldyne & Armstrong, 2010). It offers many benefits that include increased access to dermatologic services and potential reduction in costs associated with care. Teledermatology is traditionally categorized into two different models based on the technology that is employed: store-and-forward (S&F) teledermatology, and live, interactive (LI) teledermatology (Goldyne & Armstrong, 2010). While hybrid models (a combination of S&F and LI technology) are practiced at selected institutions, this chapter focuses primarily on S&F and LI models. We will present operational flows of these two technology-enabled modalities, common outcomes measures used for evaluation of teledermatology quality metrics, and economic analyses.

At the end of the chapter (in section 5), we will consider a novel, technology-independent framework for categorizing teledermatology models as well. This system relies on classification of teledermatology based on healthcare delivery models, and serves as an alternative way to organize and evaluate the provision of teledermatologic care.

2. Store-and-forward teledermatology

Store-and-forward teledermatology is an asynchronous means for providing dermatologic care, as it relies on the *asynchronous* transmission of static digital images, patient histories, and specialist recommendations rather than real-time interaction between the specialist and the patient (Goldyne & Armstrong, 2010).

In the S&F model, a medical staff personnel at the referral site typically takes images of the relevant skin condition and obtains medical history. This information is then sent to a dermatologist via a secure internet connection. The dermatologist evaluates the patient's condition asynchronously and transmits the recommendations back to the primary care provider at the referral site (Pak et al., 2009).

2.1 Outcomes measures of store-and-forward teledermatology

Teledermatology studies have assessed numerous outcomes measures, including learning effects, length of consultation, and technical aspects (Eminovic et al., 2007). We will focus this discussion on four extensively used outcomes measures: diagnostic accuracy, diagnostic reliability, clinical outcomes, and satisfaction.

2.1.1 Diagnostic accuracy of store-and-forward teledermatology

Diagnostic accuracy refers to whether or not a diagnosis is correct, based on comparison to a gold standard reference test. While histopathological review or other laboratory tests are often used as the gold standard for diagnosis, results of these types of gold standards are not always available in clinical practice in dermatology. Furthermore, it is difficult to generate cumulative data regarding accuracy, because different studies use different methodologies and standards.

Several studies have found diagnostic accuracy of S&F teledermatology to be comparable to in-person consultations (Barnard & Goldyne 2000; High et al., 2000; Krupinski et al., 1999; Oakley et al., 1997; Whited et al., 1999). Other studies have found that in-person consultation provides a significantly greater diagnostic accuracy than S&F teledermatology (Warshaw et al. 2009a; Warshaw et al. 2009b). One study found that S&F teledermatology had a significantly greater diagnostic accuracy than in-person consultation (Lozzi et al., 2007).

Different findings on diagnostic accuracy may be attributable to several factors. First, the "gold standard" used among the studies differ from in-person evaluations to pathologic evaluation. Second, patient populations and types of skin lesions differ among the various practices that were examined. Future studies can focus on tools or interventions to increase diagnostic accuracy of S&F teledermatology, such as routine incorporation of dermoscopy (Warshaw et al., 2010a).

2.1.2 Diagnostic reliability of store-and-forward teledermatology

Diagnostic reliability is a measure of concurrence in diagnosis. It may refer to intraobserver reliability (whether one examiner makes the same diagnosis in two different examinations), or interobserver reliability (whether two different examiners make the same diagnosis). These measures of reliability may evaluate either complete agreement, which refers to comparison of the most likely diagnosis, or partial agreement, which accounts for differential diagnoses.

Studies of intraobserver reliability between S&F teledermatology and in-person consultation found that agreement ranges between 31-88% for complete diagnostic agreement, and between 50-95% for partial diagnostic agreement (Table 1).

Reference	Complete Diagnostic Agreement	Partial Diagnostic Agreement
(Romero et al., 2010)	.85	.92
(Tan et al., 2010)	.74	.88
(Heffner et al., 2009)	.82	-
(Ebner et al., 2008)	.74	.90
(Pak et al., 2003)	.70	.91
(Lim et al., 2001)	.88	.95
(Taylor et al., 2001)	.31-.64	.50-.70
(Krupinski et al., 1999)	-	.76-.90

Table 1. Intraobserver Reliability for S&F Teledermatology and Conventional Care

Studies have found that interobserver reliability ranges between 41-92% for complete diagnostic agreement and between 51-100% for partial diagnostic agreement (Table 2). A review of studies between 1997 and 2005 revealed that the aggregate complete diagnostic agreement was 60%, and partial diagnostic agreement was 80% (Romero et al., 2008).

Reference	Complete Diagnostic Agreement	Partial Diagnostic Agreement
(Tan et al., 2010)	.75-.82	.83-.89
(Heffner et al., 2009)	.69	-
(Silva et al., 2009)	.87-.92	.96-1.0
(Edison et al., 2008)	.73	-
(Ebner et al., 2008)	.71-.76	.90-.97
(Bowns et al., 2006)	.55	-
(Oakley et al., 2006)	.53	.64
(Tucker & Lewis, 2005)	.56	.68
(Baba et al., 2005)	.75	-
(Mahendran et al., 2005)	.44-.48	.64-.65
(Du Moulin et al., 2003)	.54	.63
(Eminovic et al., 2003)	.41	.51
(Lim et al., 2001)	.73-.85	.83-.89
(Taylor et al., 2001)	.44-.51	.57-.61
(High et al., 2000)	.64-.77	.81-.89
(Whited et al., 1999)	.41-.55	.79-.95
(Lyon & Harrison, 1997)	.89	-
(Zelickson & Homan, 1997)	.88	-
(Kvedar et al., 1997)	.61-.64	.67-.70

Table 2. Interobserver Reliability for S&F Teledermatology and Conventional Care

Based on this data on diagnostic reliability, it appears that S&F teledermatology is a functional and reasonably reliable tool for diagnosis of skin disorders.

2.1.3 Clinical outcomes for store-and-forward teledermatology

To date, two studies have evaluated clinical outcomes of S&F teledermatology compared to conventional care, and both studies found similar outcomes for each of the two treatment modalities (Krupinski et al., 2004; Pak et al., 2007). Specifically, Pak et al. conducted a randomized controlled trial with patients randomly assigned to either conventional face-to-face care or teledermatology. Another dermatologist, blinded to the randomization, evaluated the clinical outcomes between baseline data and after four months (Table 3). The results suggest that teledermatology and conventional care result in similar outcomes (Pak et al., 2007).

		Clinical Course Rating		
		Improved	No change	Worse
Assigned Group	Teledermatology	64%	33%	4%
	Conventional Care	65%	32%	3%

Table 3. Reported Clinical Outcomes from Pak et al.

We may also consider intermediate clinical outcomes, such as (1) time-to-intervention and (2) preventable clinic visits. Time-to-intervention is usually defined as the wait time prior to being seen by a specialist after a referral has been placed. Preventable clinic visits refers to

the percentage of dermatology clinic visits that could be avoided through use of teledermatology.

The literature suggests that the use of S&F teledermatology may considerably reduce time-to-intervention. Researchers in Spain found that surgical patients managed through S&F teledermatology had a mean waiting interval 34.47 days shorter than those patients managed through conventional care (Ferrandiz et al., 2007). A similar study found that patients at primary care centers managed through teledermatology waited on average 76.31 days less than those with conventional referrals (Moreno-Ramirez et al., 2007). A study of patients at the Durham VA Medical Center found that those that received a S&F teledermatology consultation were seen on average 86 days sooner than those in the conventional system (Whited et al., 2002).

The reduced time-to-intervention may be partially due to the fact that teledermatology can help prevent unnecessary clinic visits. Indeed, studies have found that S&F teledermatology could prevent 13-58% of dermatology clinic visits (Whited, 2010).

2.1.4 Satisfaction with store-and-forward teledermatology

Satisfaction assessments may be subdivided into three categories: patient satisfaction, referring provider satisfaction, and specialist satisfaction. Studies suggest that patients were generally satisfied with receiving care through S&F teledermatology, and typically had no preference between teledermatology and usual care (Warshaw et al., 2010b). One study found that 76% of patients preferred being treated through teledermatology in order to avoid the wait time associated with a face-to-face clinic visit (Bowns et al., 2006). A common patient complaint during the S&F teledermatology process was the length of time between the consultation and being informed of the results by the primary care providers (Whited, 2010).

When referring providers were asked about their satisfaction with S&F teledermatology, referring providers provided varied feedback (Bowns et al., 2006; Collins et al., 2004; Weinstock et al., 2002; Whited et al., 2004). Many referring providers report that they improved their therapeutic and diagnostic ability due to regular feedback and interactions with the dermatologist (van den Akker et al., 2001). From the referring providers' perspective, some dissatisfaction with the S&F teledermatology process stemmed from the additional time and effort required for relaying the diagnoses to patients, prescribing the medications, or performing procedures (Bowns et al., 2006; Collins et al., 2004; Kvedar et al., 1999).

Fewer studies have evaluated satisfaction of dermatologists who practice teledermatology. While most dermatologists practicing teledermatology reported increased satisfaction (Whited, 2010), many report reduced confidence in their diagnoses (Bowns et al., 2006; Pak et al., 1999; Whited et al., 2004).

2.2 Economic considerations of store-and-forward teledermatology

We begin discussion of the economic aspects of S&F teledermatology with a brief review of common types of economic analysis. Three commonly used methods are cost minimization analysis, cost-effectiveness analysis, and cost-benefit analysis (Davalos et al., 2009). Cost-minimization analysis is a type of cost analysis that evaluates two systems that produce equivalent outcomes. Cost-effectiveness analysis compares monetary costs (cost) in the context of outcomes (effectiveness). However, this type of analysis generally considers only one outcomes measure. In comparison, cost-benefit analysis considers multiple economic costs as well as varied benefits within a system, and it generally includes multiple outcomes measures. Cost-benefit analyses are generally considered the most comprehensive type of

economic analyses. Further information regarding economic evaluation metrics may be found in Davalos et al. (Davalos et al., 2009).

Literature shows that S&F teledermatology is generally economically viable (Table 3). While studies differed in their economic perspective and modality of S&F teledermatology delivery (e.g. triage, consultation, versus provision of care), analyses have generally established that S&F teledermatology offers a cost-effective means of providing dermatologic care especially for those living in geographically isolated communities or medically underserved communities (Pak et al., 2009; Whited et al., 2003). For example, in a cost-minimization analysis that adopted the perspective of the U.S. Department of Defense, Pak et al. concluded that the use of teleconsultations through S&F technology reduced overall costs compared to conventional care (Pak et al., 2009).

Similarly, Whited et al. performed a cost analysis of a consultative model using S&F technology from the perspective of the U.S. Department of Veterans Affairs (Whited et al., 2003). The authors found that teleconsultations are $15 more costly per patient compared to face-to-face consultation. In this study, effectiveness was defined as time-to-specialist evaluation. They found that having teledermatology consultations resulted in shorter time-to-specialist evaluation and was overall more cost-effective. Further analyses showed that, from a *societal* perspective, S&F teleconsultations would be even less costly after accounting for patients' travel time and productivity lost through face-to-face care (Whited et al., 2003).

When S&F teledermatology was used as a primary method for triaging cases appropriate face-to-face encounters, researchers found that this was an economically viable means for prioritizing patients requiring dermatologic care (Ferrandiz et al., 2008; Moreno-Ramirez et al., 2009). By comparing S&F teledermatology and conventional referrals to a skin cancer clinic in Spain, Moreno-Ramirez et al. conducted a cost-identification and cost-effectiveness analysis from a societal perspective (Moreno-Ramirez et al., 2009). The investigators assessed costs associated with travel, lost-productivity, and healthcare delivery. Effectiveness was defined as the wait-time to in-person consultation after the referral. The authors found that teledermatology triage was more cost-effective; specifically, teledermatology yielded cost-savings of €49.59 per patient compared with conventional face-to-face care (Moreno-Ramirez et al., 2009). These findings were corroborated by another cost-effectiveness study in Spain, where the investigators found that the use of teledermatology saved €122.02 compared to conventional care (Ferrandiz et al., 2008).

Reference	Type of Analysis	Teleconsultation	Conventional	Perspective
Provision of Care				
(Pak et al., 2009)	Cost-minimization	$340 / patient	$372 / patient	Department of Defense
(Whited et al., 2003)	Cost / Cost-effectiveness	$36.40 / patient	$21.40 / patient	Department of Veterans Affairs
Triage				
(Moreno-Ramirez et al., 2009)	Cost-identification / Cost-effectiveness	€79.78 / patient	€129.37 / patient	Societal
(Ferrandiz et al., 2008)	Cost / Cost-effectiveness	€156.40 / patient	€278.42 / patient	Societal
$ - US dollars; € - euros				

Table 4. Economic Analyses of Store-and-Forward Teledermatology

3. Live, Interactive Teledermatology

Live, interactive teledermatology involves synchronous interaction between the specialist and patient (Goldyne & Armstrong, 2010). Via videoconferencing or web-conferencing, the specialist obtains a clinical history, examines the patient in real-time, and communicates recommendations to the patient and the primary care provider (Wootton et al., 2000).

3.1 Outcomes measures of Live, Interactive Teledermatology

We will consider the same outcomes measures for LI teledermatology as we did for S&F teledermatology: diagnostic accuracy, diagnostic reliability, clinical outcomes, and satisfaction.

3.1.1 Diagnostic accuracy of LI Teledermatology

Studies comparing diagnostic accuracy of LI teledermatology to pathologic diagnosis are not currently available. Studies comparing diagnoses between LI teledermatology and in-person consultation generally show diagnostic agreement, and will be discussed further under diagnostic reliability.

3.1.2 Diagnostic reliability of Live, Interactive Teledermatology

Studies of intraobserver reliability between LI teledermatology and in-person consultation show complete diagnostic agreement in 59-75% of cases, and partial agreement in 76-87% of cases (Table 5).

Reference	Complete Diagnostic Agreement	Partial Diagnostic Agreement
(Loane et al., 1998b)	.71	.87
(Gilmour et al., 1998)	.59	.76
(Oakley et al., 1997)	.75	.82

Table 5. Intraobserver Reliability for LI Teledermatology

Interobserver reliability between LI teledermatology and in-person consultation ranges from 54-80% for complete diagnostic agreement, and 79-99% for partial agreement (Table 6). A review of aggregate data indicates that complete diagnostic agreement is 70%, while partial diagnostic agreement is 84% (Romero et al., 2008).

Reference	Complete Diagnostic Agreement	Partial Diagnostic Agreement
(Nordal et al., 2001)	.72	.86
(Phillips et al., 1998)	.59	-
(Loane et al., 1998b)	.60	.76
(Lowitt et al., 1998)	.80	-
(Gilmour et al., 1998)	.54	.80
(Lesher et al., 1998)	.78	.99
(Phillips et al., 1997)	.77	-

Table 6. Interobserver Reliability for LI Teledermatology

3.1.3 Clinical outcomes for LI Teledermatology

One study evaluated clinical outcomes for LI teledermatology compared to conventional care. In a retrospective analysis of patients who had two or more teledermatology consultations, Marcin et al. found that diagnosis, treatment, and patient improvement data for the teledermatology patients were consistent with existing literature regarding conventional care (Marcin et al., 2005).

Intermediate outcomes measures include (1) preventable clinic visits and (2) time for completion of consultation. Similar to the S&F modality, LI teledermatology can prevent unnecessary clinic visits. Studies found that 44.4-82% of clinic visits could be avoided through the use of LI teledermatology (Whited, 2010).

LI teledermatology can decrease total time necessary to complete a consultation visit from the patient's perspective. For example, researchers in New Zealand found that, compared to a clinic visit, the use of LI teledermatology saved patients an average of 3.45 hours of time, primarily due to reduced traveling time (Oakley et al., 2000). However, LI teledermatology does not necessarily reduce consult time for the dermatologist (Loane et al., 1999, 2001b; Oakley et al., 2000).

3.1.4 Satisfaction with Live, Interactive Teledermatology

As stated previously, satisfaction in teledermatology is categorized into patient satisfaction, referring provider satisfaction, and dermatologist satisfaction. Patients reported that they were equally satisfied with LI teledermatology and conventional care and had no strong preference for one modality over another (Whited, 2010). Some patients reported initial discomfort due to the presence of camera (Gilmour et al., 1998; Loane et al., 1998a).

Relatively few studies evaluated referring provider satisfaction in LI teledermatology. While there was some dissatisfaction associated with technical difficulties, most referring providers report being satisfied with the LI teledermatology (Gilmour et al., 1998; Jones et al., 1996).

Similar to dermatologists who practice S&F teledermatology, dermatologists who practice LI teledermatology report being satisfied with practicing LI teledermatology. However, when compared to in-person consultation, dermatologists expressed lower confidence in their diagnoses (Artiles Sanchez et al., 2004; Lowitt et al., 1998).

3.2 Economic considerations of Live, Interactive Teledermatology

Economic analyses of LI teledermatology yielded mixed conclusions regarding its economic sustainability. While some studies have shown LI teledermatology to be cost-effective, others suggested that it may be more costly than conventional care. In a cost-minimization analysis from a societal perspective, authors from New Zealand found that teledermatology consultations using LI technology appeared less costly than that of face-to-face care, especially when patients have longer travel distances (Loane et al., 2001b). In another cost-minimization study of LI teledermatology in the U.S., investigators found that consultative teledermatology using LI technology also appears to be less costly than face-to-face care from a provider perspective (Armstrong et al., 2007).

In a cost-benefit analysis from the societal perspective, Wootton et al. found that a LI teleconsultation system in the United Kingdom was more costly than face-to-face care. Sensitivity analyses showed that LI teledermatology consultations could be a less costly alternative if patients travelled longer distances for in-person consultations and incurred greater lost-productivity costs (Wootton et al., 2000).

Reference	Type of Analysis	Teleconsultation	Conventional	Perspective
(Dekio et al., 2010)	Cost-effectiveness	¥26,040 / week	¥60,500 / week	Societal
(Armstrong et al., 2007)	Cost-minimization	$274 / hour	$346 / hour	Healthcare provider
(Loane et al., 2001b)	Cost-minimization	NZ$279.23 / patient	NZ$283.79 / patient	Societal
(Loane et al., 2001a)	Cost-benefit	£146.48 / patient	£47.13 / patient	Urban Societal
(Loane et al., 2001a)	Cost-benefit	£180.22 / patient	£48.77 / patient	Rural Societal
(Wootton et al., 2000)	Cost-benefit	£132.10 / patient	£48.73 / patient	Societal
(Lamminen et al., 2000)	Cost	FM 18,627 (total cost)	FM 18,034 (total cost)	Societal
(Bergmo, 2000)	Cost-minimization	NKr 470,780 (total cost)	NKr 1,635,075 (total cost)	Healthcare provider
(Chan et al., 2000)	Cost / Cost-effectiveness	HK$57.7 / patient	HK$322.8 / patient	Healthcare provider
(Burgiss et al., 1997)	Cost	$141 / patient	$294 / patient	Societal
¥ - yen; € - euros; $ - US dollars; NZ$ - New Zealand dollars; £ - pounds; FM – Finnish marks; NKr – Norwegian kroners; HK$ - Hong Kong dollars				

Table 7. Economic Analyses of Live, Interactive Teledermatology

4. Comparison of store-and-forward and Live, Interactive Teledermatology

Approximately 42% of the United States population lives in medically underserved areas (Suneja et al., 2001). Both S&F and LI teledermatology can increase access to specialty care especially for populations living in rural or medically underserved areas (Hailey, 2005; Kailasam et al., 2010; Pak et al., 2007; Vallejos et al., 2009).

S&F and LI teledermatology present distinct advantages. S&F teledermatology appears to be very cost-effective. Specifically, compared to LI teledermatology, S&F teledermatology requires less equipment or technology costs (Pak, 2008; Watson, 2009). The requirements for administrative support and overhead also appear to be less for S&F teledermatology. Finally, the asynchronous nature of S&F modality affords greater scheduling flexibility for patients and dermatologists since coordinated appointments with specialists are not required (Finch et al., 2007; Watson, 2009). LI teledermatology, on the other hand, more closely mirrors a conventional face-to-face consultation because the specialist can interact with patients and a referring provider in real-time.

S&F and LI teledermatology have their respective disadvantages as well. In S&F teledermatology, because the ability of the dermatologist to diagnose and provide useful

recommendations depends solely on the quality of images and clinical history, suboptimal images or incomplete clinical history can be frustrating for the dermatologist. Furthermore, S&F teledermatology does not allow the development of a patient-dermatologist relationship compared to LI teledermatology (Grenier et al., 2009; Onor & Misan, 2005). LI teledermatology presents alternative challenges in terms of scheduling, coordination, and costs.

Given the unique benefits that each modality offers, some providers have recently started to employ a hybrid model. In the hybrid model, the clinical encounters are conducted via videoconferencing or webconferencing, and the dermatologist reviews static digital images that were acquired by a digital camera prior to the encounter and sent to them during the encounter. Current research efforts are investigating the relative effectiveness of such hybrid systems (Baba et al., 2005; Romero et al., 2010). For example, Baba et al. found that a hybrid modality increased diagnostic accuracy by 7-9%, compared to S&F teledermatology alone (Baba et al., 2005).

5. Novel classification teledermatology based on healthcare delivery models

To date, teledermatology has been categorized by the technology it uses--S&F and LI technology. An alternative model to frame teledermatology is based on the type of healthcare delivery. Specifically, independent of the type of technology employed, we can arrange teledermatology delivery into (1) triage, (2) consultative, and (3) direct-care models. This technology-independent, healthcare delivery-based framework is accessible to policy makers and other stakeholders involved in health policy.

5.1 Triage model

In the triage model, all dermatology referrals are first seen through teledermatology. A specialist reviews the cases rapidly with the goal of prioritizing which patients are suitable for in-person evaluation. The triage model prioritizes patients based on the severity and urgency of their skin condition. This modality has been primarily practiced in Europe in prioritization patients with cutaneous malignancies (Ferrandiz et al., 2007; Moreno-Ramirez et al., 2007).

5.2 Consultative model

In the consultative model, the referring providers decide which dermatology referrals are appropriate for teledermatology evaluation. From the dermatologist's perspective, the primary goal of the consultative model is to provide detailed and useful recommendations to the primary care provider. In this healthcare delivery model, the dermatologist reviews the cases via either S&F or LI technology and provides detailed recommendations to the primary care provider. The primary care provider assumes responsibility for communicating with the patient and carrying out the recommendation plans. The consultative model is currently the most common model in the United States (Goldyne & Armstrong, 2010).

5.3 Direct-care model

In the direct-care model, the dermatologist assumes the responsibility of communicating and treating the patient. This model differs significantly from the triage or consultative

model in that the dermatologist is responsible for caring for the patient. The provision of direct care includes evaluation, communicating the treatment plan to the patient, writing prescriptions, carrying out laboratory evaluations, and monitoring disease progression.
The direct-care model has generally been practiced using S&F technology and in research settings (Chambers et al., 2010; Parsi et al., 2010; Watson et al., 2010).

6. Conclusion

As healthcare delivery becomes more patient-centered and distance-independent (Hibbard, 2004; Hogarth et al., 2010; Robinson et al., 2011), proper application of teledermatology offers a versatile means of providing high quality care to patients in their own communities. Teledermatology can be used in various healthcare delivery modalities, including triage, consultation, and direct care.
In addition to gathering the support of healthcare workers and patients for these newer models of healthcare delivery, those who work at the forefront of telemedicine need to also advocate for policy changes and technological innovations to continually improve the quality and experience of telemedicine. It is likely that the cost of technology will decline as the reliability and user-interface of technology continually improve. In this healthcare environment, innovations in teledermatology serve as examples for emerging paradigms in healthcare delivery.

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Telemedicine is a rapidly evolving field as new technologies are implemented for example for the development of wireless sensors, quality data transmission. Using the Internet applications such as counseling, clinical consultation support and home care monitoring and management are more and more realized, which improves access to high level medical care in underserved areas. The 23 chapters of this book present manifold examples of telemedicine treating both theoretical and practical foundations and application scenarios.

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