1. Title Page

The cost-effectiveness of skin cancer referral and consultation using teledermoscopy in Australia

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Key Points

Question: Is teledermoscopy cost-effective for skin cancer referral and triage in Australia?

Findings: Store-and-forward teledermoscopy skin cancer referral was estimated to cost AU$54.64 per person more than usual care, but enabled clinical resolution to be achieved 26 days earlier. The incremental cost per day saved to clinical resolution was AU$2.10.

Meaning: Incorporating teledermoscopy as a referral method for skin cancer in Australia has the potential to benefit patients by providing earlier clinical resolution at additional cost to Medicare.

2. Abstract

Importance: International literature has shown that teledermoscopy referral may be a viable method for skin cancer referral, however no economic investigations have occurred in Australia.

Objective: To assess the cost-effectiveness of teledermoscopy as a referral mechanism for skin cancer diagnosis and management in Australia.

Design: Cost-effectiveness analysis using a decision-analytic model.

Setting: Primary care

Participants: Australian general population (modelled)

Intervention: We compared the costs of teledermoscopy referral (electronic referral containing digital dermoscopic images) versus usual care (a written referral letter) for specialist dermatologist review of a suspected skin cancer.

Main outcome measures: Cost and time in 'days to clinical resolution', where clinical resolution was defined as diagnosis by a dermatologist or excision by a general practitioner. Probabilistic sensitivity analysis was performed to examine the uncertainty of the main results.

Results: Time to clinical resolution was 26 days earlier with teledermoscopy referral compared with usual care alone (95%Credible interval (CrI) 13 to 38). The estimated mean cost difference between teledermoscopy referral ($318.39) versus usual care ($263.75) was $54.64 (95%CrI $22.69 to $97.35) per person. The incremental cost per day saved to clinical resolution was $2.10 (95%CrI $0.87 to $5.29).

Conclusion and Relevance: Using teledermoscopy for skin cancer referral and triage in Australia will cost $54.64 extra per case on average, but will result in clinical resolution 26 days sooner than usual care. Implementation recommendations depend on the preferences of the Australian health system decision makers for either lower cost or expedited clinical

resolution. Further research around the clinical significance of expedited clinical resolution and its importance for patients could inform implementation recommendations for the Australian setting.

3. Text

Introduction

Skin cancer presents a global health challenge. In Australia, melanoma accounts for over 10% of all diagnosed and reported cancers, with an estimated 13,280 new cases diagnosed in 2016[1]. The incidence of melanoma is increasing. Keratinocyte skin cancers (squamous and basal cell carcinomas) and other skin cancers, are not nationally reported and occur between 10 and 20 times more often than melanoma [1].

Teledermatology is the provision of the dermatologic care at a distance using information and communication technology. Teledermatology often uses store-and-forward communication, where digital images of a skin lesion are captured, typically in primary care, and subsequently forwarded to a dermatologist along with clinical information for review or management advice. In addition to the provision of virtual consultations, teledermatology can also be used to facilitate the triage of referrals for specialist care. [2-5]. When compared to a written referral for specialist care, the visual information included in a teledermatology referral provides extra information to assist with appropriate triage and patient management. Teledermatology referrals can result in earlier assessment and treatment[6], and reduced waiting times and waiting lists[7]. When clinically indicated, some patients do not need to be seen by a dermatologist and instead can be managed by their general practitioners (GPs) often under advice from a dermatologist[8-10].

Dermoscopy is a non-invasive diagnostic technique that links clinical dermatology and dermatopathology of pigmented and non-pigmented skin lesions by enabling the visualisation of morphological features not seen by the naked eye [11]. Teledermoscopy is a form of teledermatology that specifically involves the store-and-forwarding of digital dermoscopic

images. When compared to other imaging techniques, teledermoscopy improves diagnostic accuracy[12,13]. Teledermoscopy is not currently reimbursed under Medicare (Australia's universal health scheme funded by the federal government).

At present there are no published economic evaluations for teledermoscopy services specific to the Australian healthcare system, and there are few international studies available[14]. The implementation of new models of care requires information on their comparative cost-effectiveness. Therefore, the purpose of this study was to examine the cost-effectiveness of teledermoscopy as a referral mechanism for skin cancer diagnosis in Australia and determine its value for improving the management of skin cancer.

Methods

Overview

The cost-effectiveness of teledermoscopy referral for a suspected skin cancer was compared to usual care using a decision-analytic model. A teledermoscopy referral is an electronic referral to dermatologist containing digital dermoscopic images and clinical information. Whereas, usual care is a written referral from a GP containing clinical information only. An ethics waiver was granted by The University of Queensland Human Ethics Research Office.

The decision-analytic model was developed in TreeAge Pro© software (Release 2.1, 2016). The model represented pathways of clinical management of suspected skin cancer in a general adult population. The model has two arms, one representing usual care for suspected skin cancer in Australia and one representing the teledermoscopy referral intervention (

Figure 1~~Figure 1~~).

The end point was 'clinical resolution' defined as diagnosis by a dermatologist or excision of

lesion by a GP. Diagnostic outcomes were melanoma, keratinocyte skin cancer (squamous cell carcinoma or basal cell carcinoma), and benign neoplasms (clinically and dermoscopically mimicking melanoma or a keratinocyte skin cancer). Costs were estimated from the perspective of the Australian Commonwealth Government (administrators of the Medical Benefits Scheme, MBS), and included the costs of consultation, excision, and histopathology. Histopathology confirmation of excised lesions is required before claiming items on the MBS to ensure correct itemisation and payment for healthcare providers[15].

Comparative treatments

In Australia, usual care for a patient begins with a visit to a GP. Suspicious skin lesions may be detected during routine skin checks or opportunistically when patients visit their GP for a different purpose. After examining the area of concern and performing a full skin check, the GP can perform a biopsy or excision for histopathology, or refer the patient to a dermatologist for management. If referral is selected; the GP will write a referral letter and forward it to a nominated dermatologist, or to the patient who can submit to a dermatologist of their choice. When the patient has a consultation with the dermatologist, the dermatologist will undertake a full skin examination with or without a dermoscope, take dermoscopic images where appropriate, and if necessary perform a biopsy or excision. This process may occur across single or multiple visits with either the GP and/or dermatologist.

For teledermoscopy referral, rather than writing referrals, the GP captures and sends a teledermoscopy image with clinical notes to any participating dermatologist. Once reviewed by a dermatologist, the teledermoscopy information could either be used to advise the GP of management options (e.g. to excise or monitor), or if necessary, schedule the patient for an in-person dermatologist consultation.

Model inputs

Data estimates that informed the model were sourced systematically from literature searches and government databases. Probability data were sourced from international publications that had performed studies with similar usual care and teledermoscopy referral intervention (Table 1). The Australian Bettering the Evaluation and Care of Health (BEACH) report informed treatment estimates for proportion of occasions when GPs chose monitoring (no active treatment) for suspicious lesions, or rate of referral to a dermatologist (Table 1)[16]. The BEACH program runs out of the University of Sydney and collects data about the clinical activities of Australian GPs.

Cost data to inform the model were sourced from the Australian Department of Health MBS (Table 1). The dermatologist teledermoscopy consult fee was set to be the same as the dermatologist in-person consultation fee, $72.75, aligning with the Medicines Advisory Committee Applications for asynchronous store-and-forward reimbursement [17]. Costs for excision of melanoma, keratinocyte skin cancer, and benign neoplasm were informed by relevant MBS item codes (Table 1)[18]. Since there are multiple MBS item codes for each type of skin lesion, a single price per lesion type was calculated using a weighted average. Average weighted costs were calculated using MBS data from March 2013 to April 2014, this timeframe was selected to align with the BEACH report [15,16].

The measure of benefit for this analysis was ‘days to clinical resolution’. Clinical resolution was diagnosis by a dermatologist, or excision and histopathology by a GP. The time in days between a GP consultation and excision of a suspected skin cancer was set to one day, and is the same in both arms of the model. All other time information was taken from a prospective

cohort study performed in New Zealand with 300 participants in 2012[8]. This study was selected because of the comparability of the New Zealand health system and skin cancer risk to Australia, alternatives were cohort studies from Spain or the Unitised States[4,19].

Analyses

The model performed an expected values analysis by aggregating the probabilities and costs in the pathways to calculate the mean cost per person. The incremental cost-effectiveness ratio was calculated by dividing the difference in costs of the two options by the difference in days to clinical resolution (benefit). Cost inputs were in 2016 Australian dollars (AUD$).

One-way sensitivity analysis was performed by separately varying all model inputs within plausible ranges of high and low values (from relevant sources or imputed, outlined *Table 1*~~Table 1~~). Alternative probabilities were extracted from the published studies (*Table 1*~~Table 1~~). Frequencies of doctors' visits and pathology testing varied between one and three visits/tests which in turn affected service costs (*Table 1*~~Table 1~~).

Probabilistic sensitivity analysis was undertaken by re-sampling the cost and probabilities (concurrently) within pre-specified distributions (*Table 1*~~Table 1~~). Cost estimates and probabilities were randomly re-sampled according to gamma and beta distributions, respectively (*Table 1*~~Table 1~~). One thousand Monte Carlo simulations were run resulting in a range of plausible costs and effects. This simulation data allowed for the estimation of 95% credible interval (CrI) for model results to address the uncertainty in the model inputs. Each CrI was estimated by rank ordering the results sequentially and excluding the highest 2.5% and lowest 2.5% of values.

Results

Teledermoscopy referral had a mean cost of $318.39 per case and took nine days to clinical resolution, while the usual care cost $263.75 with 35 days to clinical resolution (*Table 3*~~Table 2~~). Therefore, teledermoscopy referral cost $54.64 (95%CrI $22.69 to $97.35) more per case than usual care alone, and was associated with a reduced time to clinical resolution by 26 (95%CrI 14 to 38) days. This resulted in an incremental cost-effectiveness ratio of $2.10 (95%CrI $0.87 to $5.29) per day saved to clinical resolution (*Table 3*~~Table 2~~).

In one-way sensitivity analyses, the most influential cost components were pathology testing (minimum of one test, maximum of two), GP consultation fee (minimum of one appointment, maximum of three), teledermoscopy dermatologist consultation fee (minimum 50%, maximum 150%) (***Figure 2***~~Figure 2~~). Influential probability components were the probability of a GP referring their patients via teledermoscopy, and the probability that after a teledermoscopy consultation the dermatologist would instruct the patient to return to their referring practitioner for diagnosis or treatment. As the number referred back to their GP decreased from 90% to 10% the incremental cost-effectiveness ratio changed from $1.55 to $6.23 per day to clinical resolution. This was to be expected as the cost-effectiveness of teledermoscopy after implementation would depend on the uptake of referrals using teledermoscopy by GPs and the number of in-person dermatologist appointments avoided. Results from the probabilistic sensitivity analyses showed costs ranging from $22.69-$97.35 per person, and for time to clinical resolution was 13-38 days. This variation in estimates meant the overall incremental cost-effectiveness ratio was estimated between $0.87-$5.29 per day saved to resolution, as shown in *Table 3*~~Table 2~~. ***Figure 3***~~Figure 3~~ shows a clear separation between the cost-effectiveness ratio of teledermoscopy and usual care; teledermoscopy had a higher cost with faster clinical resolution than usual care within the

modelled conditions.

Discussion

Teledermoscopy referral has the potential to increase the efficiency of a dermoscopic case of care, reduce unnecessary biopsies and reduce inappropriate referral for specialist consultations. This is the first study to evaluate the economic impact of teledermoscopy referral for the management of suspected skin cancers in the Australian context. Under the modelled conditions, it was found that teledermoscopy referral would on average cost an additional $54.64 per case compared to usual care but would reduce time to clinical resolution by 26 days. Although using teledermoscopy referral can increase the overall cost of treatment, the extra $54.64 per case may be a justifiable cost for the Australia government for expedited diagnosis and treatment.

Consistent with our findings, studies in other countries have demonstrated teledermoscopy services were of comparable or higher cost to usual care with positive benefits[10,14,20,21]. Internationally, teledermoscopy referral systems have been successfully piloted with similar benefits to those demonstrated by this model [8-10]. These studies showed that when used as a referral method, teledermoscopy meant that 39-88% of patients did not have to attend an in-person consultation with their dermatologist and were able to be managed by their GP[14]. Each patient referred to a dermatologist for a teledermoscopy consultation that resulted in GP management (rather than requiring an in-person dermatologist consultation) increased the cost-effectiveness of teledermoscopy referral because dermatologists attract a higher attendance fee than GPs (***Figure 2*** ~~Figure 2~~). In addition, accurate dermatologist diagnosis via teledermoscopy has the potential to avoid erroneously excising benign neoplasms, preventing excision and histopathology costs. Teledermoscopy referral can optimise triage for in-person

dermatologist appointments, due to the visual information about the condition[10,20,21]. Thereby, ensuring dermatologist appointments are available for urgent cases when required[14].

The Australasian College of Dermatologist's application to the Commonwealth's Department of Health to fund teledermoscopy under Medicare proposed an equal reimbursement for store-and-forward teledermatology compared with in-person care[17]. Reducing the consultation fee for teledermoscopy (modelled in this study as equal to the in-person dermatologist reimbursement fee) increases the cost-effectiveness of the teledermoscopy service.

To effectively implement teledermoscopy services at the substitution rates that achieve desirable cost-effectiveness a streamlined dermoscopic image capture process for general practice would be essential[7,22]. Capturing dermoscopic images and completing a digital referral form could increase general practice appointment time by as much as 11:32 minutes (range 7:02–26:44)[23], this may serve as a disincentive to GPs in the Australian fee-for-service model. Using support staff could reduce this barrier to implementation, once the GP has identified the lesions of interest, they could capture the images and complete some of the digital referral[7].

Further research around the clinical significance of expedited clinical resolution and its importance for patients could inform implementation recommendations for the Australian setting. Similarly, research into what the consumers are willing to pay for teledermoscopy given its ability to reduce the time to clinical resolution. If teledermoscopy remains unfunded by the government then patients may be willing to self-fund the service in a private capacity to reduce their travel and receive a faster specialist opinion.

Strengths and Limitations

The model examined costs and benefits from the perspective of the Australian Commonwealth Government in community outpatient settings. The results are therefore only applicable to the Australian healthcare setting. This model was not applicable to patients treated through alternate clinical pathways, including those who receive inpatient treatment in a hospital. Due to limited data regarding teledermoscopy in Australia, the model endpoint was classified as clinical resolution; either dermatologist diagnosis or excision with histopathology confirmation of diagnosis by either a GP or a dermatologist. The model does not distinguish between GPs who are working in GP clinics and those working in skin cancer clinics; referral and excision rates for the later may vary from those presented[24].

Although few previous economic models have examined the cost-effectiveness of teledermoscopy service provision, there are several randomised controlled trials and observational trials that have collected cost information alongside their clinical data[14,25]. One strength of this study is that actual cost data were used to inform our model for all items except the teledermoscopy fee.

Several costs that were excluded in the model, for example, those associated with hospital treatments or referrals managed in a hospital, biopsies, and the costs incurred by patients (co-payments and other out-of-pocket expenses). Patient-incurred costs are likely to be significant for patients who need to travel from rural areas to access metropolitan dermatologists in the usual care scenario. Australia has travel subsidy and reimbursement schemes for eligible patients, however they are only available to patients in the public hospital system, not those accessing care through community-based medical practices as described in this model.

Therefore, if teledermoscopy as described in this model was examined from a societal perspective, it would likely have superior cost-effectiveness to usual care.

Not excising benign lesions that would otherwise be removed may be an optimal outcome for teledermoscopy. The change in excision rates for benign neoplasm as a measure of effectiveness assumes that optimal clinical resolution would be to leave benign neoplasms intact. However, patients often request benign lesions be excised for cosmetic, discomfort or other reasons, therefore, the costs for benign lesion excision may have been underestimated[26,27].

Time in days to clinical resolution was taken from a New Zealand study as the best available source. This is relevant to the Australian context because New Zealand also has a very high incidence of skin cancers and a similar health system to the Australia[28]. The use of international values may have the potential to under or overestimated the time components in this model. However, the New Zealand values used to populate the model fall within the range of time in days to clinical resolution shown by other international studies. These other studies examining teledermoscopy referral reported 13-50 days when using teledermoscopy referral, and 61-138 days for usual care[8-10,29].

Conclusion

Teledermoscopy for skin cancer referral and triage in Australia will increase the cost per case, but reduce time to clinical resolution, when compared to usual care. Implementation recommendations depend on the preferences of the Australian health system decision makers for either lower cost or expedited clinical resolution.

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Mrs Centaine Snoswell, had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Snoswell, Whitty, Soyer, and Gordon.
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Drafting of the manuscript: Snoswell, Caffery, and Gordon.
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5. Figure Legends

Figure 1. Decision analytic model structure.

Figure 1 shows the decision analytic model structure, demonstrating the decision nodes and end points that were used in the model.

Figure 2. 1-way sensitivity analysis for model inputs expressed in incremental cost-effectiveness ratio values (cost per days to clinical resolution).

Figure 2 shows the output for a 1-way sensitivity analysis expressed as an incremental cost-effectiveness ratio in the form of a tornado diagram.

Figure 3. Probabilistic sensitivity analysis simulation for cost-effectiveness (cost per days to clinical resolution).

Figure 3 shows the scatter-plot output from the probabilistic sensitivity analysis simulation. It demonstrates a clear divide between the estimates for usual care and teledermoscopy care.

6. Tables

Table 1. Cost and probability estimates (rows continue on next page)

Variable	Model estimate (AUD$)	Sensitivity values		Distribution parameters	Source
		Minimum (AUD$)	Maximum (AUD$)		
Costs				**Gamma**	
GP consultation fee	$37.05	$37.05 (1 consult)	$111.15 (3 consults)	α=6.10, ʎ=0.16	MBS item 23[15]
Dermatologist consultation fee	$72.75	$72.75 (1 consult)	$145.5 (2 consults)	α=23.52, ʎ=0.32	MBS item 104[15]
Dermatologist teledermatology consult	$72.75	$36.38 (50%)	$109.125 (150%)	α=23.52, ʎ=0.32	MSAC Application (refers to MBS item 104)[15,17]
Cost of histopathology	$107.12	$107.12 (1 instance)	$214.24 (2 instances)	α=28.69, ʎ=0.27	Weighted average of MBS items 72816-18 and 72830[15]
Average cost for benign neoplasm excision	$91.72	$76.4 (lowest MBS cost)	$126.05 (highest MBS cost)	α=84.13, ʎ=0.92	Weighted average of MBS items 31200-31210[15]
Average cost for keratinocyte skin cancer excision	$157.36	$155.85 (lowest MBS cost)	$299.25 (highest MBS cost)	α=39.62, ʎ=0.25	Weighted average of MBS items 31255–31290[15]
Average cost for melanoma skin cancer excision	$250.92	$278.65 (lowest MBS cost)	$369 (highest MBS cost)	α=279.83, ʎ=1.12	Weighted average of MBS items 31300–31335[15]
Average cost for any skin cancer excision (keratinocyte or melanoma skin cancer)	$161.08	$155.85 (lowest MBS cost)	$369 (highest MBS cost)	α=21.18, ʎ=0.13	Weighted average of MBS items 31200-31210, 31255-31290, and 31300-31335[15]
Probabilities				**Beta**	
GP refer to dermatologist (usual care)	0.31	0.19	0.31	α=165.46, β=368.29	BEACH Report 2013-2014[16]
GP management condition without referral (usual care)	0.7	0.4	0.7	α=9.51, β=4.08	BEACH Report 2013-2014[9]
GP refer to dermatologist via teledermatology	0.64	0.15	0.85	α=9.60, β=5.40	Morton 2011[28]
Post-teledermatology patient return to GP for management	0.7	0.4	0.7	α=58.10, β=24.90	Snoswell, 2016[14]
Post-teledermatology patient attend in-person appointment with dermatologist	0.2879	0.02	0.8	α=3.20, β=7.93	Moreno-Ramirez 2007[4]
GP excise melanoma skin cancer	0.03	0.01	0.09	α=34.89, β=1128.11	English, 2004[30]
GP excise keratinocyte skin cancer	0.67	0.19	0.96	α=8.10, β=3.99	English, 2004[30]
Dermatologist in-person excise melanoma skin cancer	0.112	0.088	0.173	α=56.72, β=449.71	Taylor 2012[31]
Dermatologist in-person excise keratinocyte skin cancer	0.247	0.1	0.8	α=18.13, β=55.27	Taylor 2012[31]
Post-teledermatology GP consult and no action	0.2	0.2	0.8	α=12.60, β=50.4	Massone 2014[32]

Table 2~~1~~. Cost and probability estimates (rows continue from previous page)

Variable	Model estimate (AUD$)	Sensitivity values		Distribution parameters	Source
		Minimum (AUD$)	Maximum (AUD$)		
Post-teledermatology GP consult and excise melanoma skin cancer	0.01	0.01	0.09	α=3.95, β=391.05	Massone 2014[32]
Post-teledermatology GP consult and excise keratinocyte skin cancer	0.22	0.2	0.96	α=14.88, β=52.76	Massone 2014[32]
Outcome					
Time (days) from GP consult to GP excision without referral.	1	0	1	No distribution	Same on both arms, therefore set to 1.
Time (days) from GP to final resolution (excision or dermatologist appointment) in usual care	114	61	138	No distribution	Lim 2012[8,14]
Time (days) from GP to final resolution (excision or dermatologist appointment) via teledermatology	39	13	50	No distribution	Lim 2012[8,14]
Time (days) between GP teledermatology referral and GP no action	2	1	7	No distribution	Lim 2012[8,14]

Table 3~~2~~. Incremental cost-effectiveness analysis

Group	Mean Cost ($AUD)	Mean time to clinical resolution (days)
Usual care	$263.75	35
Usual care with teledermoscopy	$318.39	9
Difference	$54.64 (95%CrI $22.69 to $97.35)	26 (95%CrI 13 to 38)
Incremental cost-effectiveness ratio	$2.10 (95%CrI $0.87 to $5.29) per day saved to clinical resolution	