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ORIGINAL ARTICLE

Economic Analysis of a Three-Arm RCT Exploring the Delivery of Intensive, Prophylactic Swallowing Therapy to Patients with Head and Neck Cancer During (Chemo)Radiotherapy

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Abstract

Research advocates for the use of intensive, prophylactic swallowing therapy to help reduce the severity of dysphagia in patients receiving (chemo)radiotherapy ([C]RT) for head/neck cancer (HNC). Unfortunately, the intensity of this therapy, coupled with growing patient numbers and limited clinical resources, provides challenges to many international cancer facilities. Telepractice has been proposed as a potential method to provide patients with greater support in home-practice, whilst minimising burden to the health service. This study investigated the clinical and patient-attributable costs of delivering an intensive, prophylactic swallowing therapy protocol via a new telepractice application "*SwallowIT*" as compared to clinician-directed FTF therapy and independent patient self-directed therapy. Patients ($n = 79$) with oropharyngeal HNC receiving definitive (C)RT were randomised to receive therapy via a: clinician-directed ($n = 26$), patient-directed ($n = 27$), or *SwallowIT*-assisted ($n = 26$) model of care. Data pertaining to health service costs (service time, consumables, therapy resources), patient-attributable costs (travel and wages) and patient-reported health-related quality of life (QoL) (AQoL-6D) were collected. *SwallowIT* provided a cost-efficient model of care when compared to the clinician-directed model, with significant cost savings to both the health service and to HNC consumers (total saving of $1901.10 AUD per patient; $p < 0.001$). The *SwallowIT* model also proved more cost-effective than the patient-directed model, yielding clinically significantly superior QoL at the end of (C)RT, for comparable costs. Overall, when compared to the alternate methods of service-delivery, *SwallowIT* provided a financially viable and cost-effective method for the delivery of intensive, prophylactic swallowing therapy to patients with HNC during (C)RT.

Keywords Deglutition · Deglutition disorders · Head and neck cancer · Telepractice · Prophylactic swallowing therapy · Cost-effectiveness · Economic analysis

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Introduction

Head and neck cancer (HNC) is a common and complex disease which poses a significant global economic burden to healthcare institutions, patients and society [1–3]. Studies evaluating the economic burden of HNC internationally have demonstrated extensive health service utilisation and associated costs, with figures in excess of $85,000 USD per patient reported for acute and follow-up care [4, 5]. With the incidence of HNC continuing to grow [6], and survival rates improving [7, 8], increasing strain is being placed on existing healthcare resources. As such, there is growing recognition of the importance of "value-driven healthcare" [9, 10], and the need to optimise not only patient outcomes, but also the cost-efficiency of oncology services [11, 12].

In speech-language pathology (SLP) management of HNC, an area of health-service utilisation which has increased substantially in recent years relates to the provision of intensive, prophylactic swallowing therapy. Growing evidence suggests that the provision of intensive, daily prophylactic swallowing therapy during (chemo)radiotherapy ([C]RT), can reduce the severity of dysphagia post-(C)RT and improve functional outcomes for patients with HNC [13–19]. Preliminary research has also provided promising cost-effectiveness data for providing prophylactic swallowing therapy, as compared to intervening reactively with patients after (C)RT has been completed [20].

Unfortunately, there are key challenges for the delivery of intensive prophylactic swallowing therapy to patients with HNC in the clinical setting. Published exercise protocols are highly resource-intensive, placing substantial demands on already limited specialist HNC SLP resources [21–23]. Hence providing daily swallowing therapy via a clinician-directed model of therapy (i.e. daily, face-to-face (FTF) sessions with a SLP), is ultimately non-viable for many cancer centres due to existing service constraints. Furthermore, it is recognised that there is significant additional patient burden associated with attending additional SLP therapy sessions on top of scheduled radiotherapy treatment appointments [24, 25].

This calls for consideration of alternate service-delivery models which can enable the delivery of efficacious prophylactic swallowing therapy whilst also helping to minimise the burden on both health services and consumers. A service model which uses telepractice, the application of telecommunications technology to deliver assessment/management at a distance, may provide a potential solution. Telepractice is evolving as a clinically and financially viable model for providing specialist oncological and SLP services to patients with HNC [26–33]. To date, the main use of telepractice within HNC management has been via synchronous telepractice methods (e.g. real-time videoconferencing) to assist with diagnosis and assessment [27, 28, 33]. These synchronous telepractice models are instrumental in overcoming costs associated with distance and travel for the patients [28]. However, they still require real-time clinician presence, and thus provide limited opportunity to relieve the demands placed on clinical services by intensive therapeutic services.

Asynchronous telepractice models, however, provide an ideal platform for delivering intensive therapy services, as they allow patients to complete their therapy at home, with data stored and forwarded to clinicians to review at a later date [34]. Whilst to date there have been limited applications of this technology in SLP management of HNC, there have been successful applications in other areas of SLP practice requiring the provision of intensive therapy, including aphasia rehabilitation. Such research has provided promising evidence for the use of asynchronous telepractice to support patient home-practice, and alleviate burden on SLP services, particularly clinician time [35–37]. However, to date there is limited research exploring the real costs of delivering asynchronous telepractice services, as compared to traditional FTF models [38]. Thus, while research supports in principle the application of asynchronous telepractice to the delivery of prophylactic swallowing therapy to patients with HNC, further research is required to determine the financial utility of this model in the context of HNC care.

In light of this potential for asynchronous telepractice to provide a cost-efficient model for delivering intensive therapy, a new asynchronous telepractice application, "*SwallowIT*", was developed. *SwallowIT* provides a structured and supported home-practice model to assist patients with HNC to complete intensive prophylactic swallowing therapy during (C)RT [39]. The aim of current study was to investigate the costs to the health service and patients associated with the *SwallowIT* model, as compared to two alternate methods of service delivery: (1) clinician-directed FTF therapy; and (2) independent patient-directed therapy without *SwallowIT* (current standard care across many international cancer institutions [15, 23]. It was hypothesised that the *SwallowIT* model would provide a more cost-efficient method of service-delivery compared to clinician-directed therapy, and would require minimal additional costs beyond the patient-directed model.

Methods

Participants, Facility and Sample Size

This study was a single centre, three-arm parallel group trial with 1:1:1 stratified random allocation. Participants were recruited from the Metro South Radiation Oncology Service (MSROS), a tertiary cancer centre in Brisbane, Australia. Inclusionary criteria were as follows: adults ($\geq$ 18 years) diagnosed with oropharyngeal squamous cell carcinoma (SCC) planned for curative-intent (C)RT. Exclusionary criteria were as follows: (1) premorbid dysphagia or cachexia resulting from a medical condition other than HNC, (2) non-English speaking, (3) significant cognitive, vision, hearing or physical dexterity impairments deemed by the radiation oncology physician at a level prohibitory to participating in the study. Ethical approval was obtained from the Metro South Human Research Ethics Committee in Brisbane, Australia (HREC/13/QPAH/153). All participants provided written informed consent at time of recruitment. The study was conducted according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines [40].

This study forms part of a comprehensive research program evaluating the efficacy and feasibility of delivering prophylactic swallowing therapy to patients with HNC during (C)RT via three different service-delivery models. The research program was powered for the primary aim which was to determine change in patients' functional swallowing outcomes (26 patients per group needed for 80% power (two-tailed at $p = 0.05$), allowing for 10% attrition = 78 participants in total).

Procedure

Participants were stratified by oral intake status at baseline, then randomised to receive prophylactic swallowing therapy via one of the three different service-delivery models: (1) technology-assisted therapy using the "*SwallowIT*" therapy application, (2) clinician-directed FTF therapy, and (3) independent patient-directed therapy (current standard care at MSROS). Stratified randomisation was employed to control for the potential influence of pre-treatment swallowing function on post-treatment swallowing outcomes (primary clinical endpoint of RCT). The conditions of each service-delivery model are outlined in Fig. 1. All participants received: (1) FTF education with an SLP to provide general education re (C)RT side-effects and to outline the preventative exercise program, (2) weekly, joint speech-language pathology/nutrition and dietetics (SLP/DN) sessions during (C)RT to monitor side-effects, swallowing and nutrition (a total of six sessions during (C)RT), and (3) 6 weeks of prophylactic swallowing therapy as per their randomised group allocation, starting in week one of radiation treatment.

To ensure internal consistency in therapy provided, all participants completed the "Pharyngocise" exercise protocol [13] which included five swallowing exercises (sustained falsetto, tongue press, effortful swallow, Therabite™ jaw stretch, and Therabite™ jaw strengthening), completed five days per week, for the first 6 weeks for (C)RT. The clinician-directed and *SwallowIT* groups used the Therabite™ as per the published Pharyngocise protocol; however, participants in the patient-directed group were provided with stacked tongue depressors to complete their jaw exercises, as it was not standard care within MSROS to provide the Therabite™ at the time of the study. Whilst the content of the exercise program was the same in each group, the nature of service-delivery varied. The telepractice group completed their therapy at home via the "*SwallowIT*" application on an ASUS TabSmart computer tablet which was specifically designed to provide structure and support for home-practice [39]. The clinician-directed group received five additional FTF therapy sessions with the SLP per week, as per the original protocol [13]. The patient-directed group received no additional supports and were encouraged to complete their therapy independently at home.

Outcome Measurements

A range of parameters pertaining to the efficacy and cost-efficiency of the three service-delivery models were collected prospectively, of which only the parameters used in the cost analysis are reported here. The primary cost measure was the cost to the health service for delivering the intervention via the three service-delivery models. The secondary outcome measures were the patient-attributable costs for each model (including travel and time costs) and health-related quality of life (QoL).

Health Service Costs

Costs to the health-service for each service-delivery model were estimated based on the relative costs of the clinical services and associated consumables required for the three models (Table 1). This included the costs associated with (1) pre-treatment education, (2) weekly SLP/DN sessions, and (3) prophylactic swallowing therapy sessions (FTF for clinician-directed, home-based for *SwallowIT* and patient-directed). To facilitate analysis, nine clinicians (five DNs, four SLPs) who were working at MSROS during the time of the study completed a purpose-built survey regarding their clinical time and resource use associated with providing each of these types of services to the study

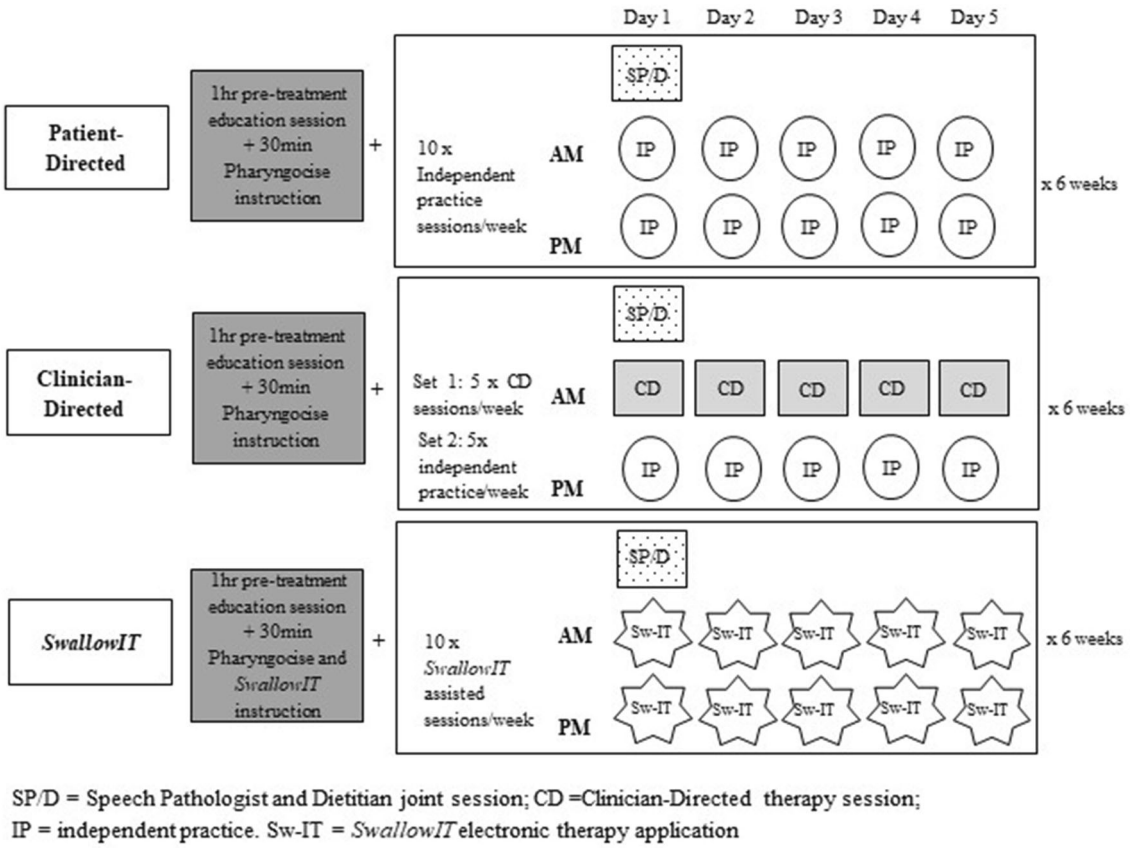

Fig. 1 Details of the (1) patient-directed, (2) clinician-directed, and (3) SwallowIT service-delivery models incorporating pre-treatment education and on-treatment practice schedules

Table 1 Breakdown of costs by type for each service-delivery model

Type of cost	*SwallowIT*	Clinician directed	Patient directed
Health-service costs			
Pre-treatment education (staff costs + consumables)	$228.65	$228.65	$228.65
SLP/DN session			
Clinician time per week	$83.35	$83.35	$83.35
Early (C)RT consumables per week	$7.40	$7.40	$7.40
Late (C)RT consumables per week	$25.41	$25.41	$25.41
SLP-directed prophylactic swallowing therapy per session (staff costs only)	N/A	$42.90	N/A
Therapy resources			
Therabite™ per patient	$500	$500	N/A
Tongue depressors per patient	N/A	N/A	$4.20
Computer tablet per patient	$33	N/A	N/A
Internet cost per patient	$6	N/A	N/A
SwallowIT app cost per patient	$15.30	N/A	N/A
Reimbursement	$2695	$7807	$2695
Patient-attributable costs			
Average travel cost per session	$97.20	$97.20	$97.20
Average patient time cost per session	$38.60	$38.60	$38.60

participants. Their responses were averaged with respect to the duration of clinical time (direct and indirect) required per type of service, and the types and numbers of consumables per type of service. To extrapolate staff costs, the average SLP/DN clinician time was multiplied by the per-minute salary rate of a health practitioner level three (HP3) therapist to estimate the cost per session. This salary rate was determined from the published annual salary of a HP3 level SLP and DN (including superannuation and overheads), assuming a standard annual salary paid for 48 weeks, at 37.5 working hours/week. This was a conservative estimate considering a HP3 professional is the base grade, and SLP/DN service provision in oncology may be covered by more senior health professionals on higher annual salary. This was a cost analysis conducted from the perspective of providing the health service. Regardless of the cost, services are reimbursed to hospital. As such reimbursement fees were not included in the cost analysis but provided for information in Table 1.

Most consumables were required in the weekly SLP/DN sessions. These were costed separately for SLPs and DNs for early (week 1–3) versus late (week 4–6) phases of the 6-week treatment period. Total consumable costs per session were extrapolated by multiplying the average number/type of consumables reported by clinicians, by per unit costs as detailed in Table 2. In addition to consumables, therapy resource costs were recorded for the three service-delivery models. This included the cost of the Therabite™ for the clinician-directed and *SwallowIT* groups, the tongue-depressors for the patient-directed group, and the telepractice equipment for the *SwallowIT* group. The Therabite™ was costed at $500 per unit, with one patient per use and no resale value. Forty tongue depressors provided to patient-directed participants each week for the 6 weeks were costed. The telepractice equipment consisted of an ASUS TabSmart computer tablet ($570), with an assumed usable life of approximately 2 years before needing replacement with no resale value. A per patient-attributable cost estimate was derived by spreading the cost of one tablet across 104 weeks to achieve a cost per week of $5.50 with the cost per patient for 6 weeks of use calculated at $33 (6 × $5.50). USB Wi-Fi internet connection for 6 weeks was also costed at $6 per patient based on an available $5 mobile data plan for 250 MB. Finally, whilst the *SwallowIT* application was provided to participants free of charge in this study, a one-off cost of $15.30 per patient (determined from averaging costs for equivalent dysphagia therapy applications currently commercially available for purchase) was added per patient in the *SwallowIT* group to represent the hypothetical cost of purchasing the application.

Table 2 Cost per unit of clinical consumables used by SLP/DN clinicians

Item	Cost ($)
Speech-language pathology consumables	
Fluids	
Thin fluids—water	Nil
Mildly thick fluids	$1.20
Moderately thick fluids	$1.20
Extremely thick fluid	$1.20
Solids	
Puree	$1.19
Diced fruit	$0.60
Biscuit	$0.11
Tongue depressor	$0.007
Nutrition and dietetics consumables	
Fortisip	$1.23
Resource Plus	$0.95
Resource 2	$1.45
Syringe for feeding	$0.40
Enteral feeding container	$3.32
External feeding line	$3.26

Prices are for single items, reported in Australian dollars and costed as at June 2016

Patient-Attributable Costs

Patient-attributable costs were calculated from data provided by purpose-built participant surveys and included (a) costs associated with return travel from their residence to MSROS for their care, and (b) the time they spent travelling and receiving treatment (i.e. SLP/DN sessions and/or prophylactic therapy sessions) (Table 1). For those patients who travelled by car, the distance to MSROS was first calculated using patient- reported addresses. Second, the cost of a one-way trip was estimated by multiplying the distance in kilometres by $0.66 (equivalent to Australian Taxation Office estimates of the vehicle cost of travel). However, as participants would otherwise be attending the clinic to receive their (C)RT, travel costs were estimated but not included the total simulated costs. That is, there is no marginal cost of travel to patients to attend SLP/DN sessions.

For those patients who were employed at time of treatment, the opportunity cost of patients' time per session of treatment was estimated based on the average patient-reported time spent receiving care at MSROS multiplied by the national weekly average wage of $1145.60 (as at November 2016, assuming an average working week of 40 h). For the patients not employed, the weekly pension rate of $873.92 was used. To avoid any potential bias in patient estimates of travel and time costs per trip, which would otherwise be equal regardless of service-delivery

model, the average per patient per session cost estimate for all patients was used across all treatment arms.

Health-Related Quality of Life

To measure differences in the change in health-related QoL, the AQoL-6D [41] was used. Participants completed the 20-item instrument at two time-points: (1) at baseline; and (2) on completion of (C)RT. Australian utility weights were then applied to estimate utility scores [41]. Missing values in the data bases were imputed within each dimension for patients who had partially completed the questionnaire based on AQoL-6D protocols [41].

Data Analysis

All costs were represented in Australian dollars (AUD). All statistical analyses were made using Stata 13.1 software (StataCorp, 2013). Estimates with respect to (a) health service costs and (b) patient-attributable costs were simulated for each service-delivery model, as per the breakdown in Table 3. From this, two cost analyses were undertaken. Firstly, total simulated costs were computed for each service-delivery model, using the procedure that was followed in the research study (Table 3). Due to the skewed nature of cost data, each cost component was bootstrapped (1000 iterations) for each visit for each of the patients in the three service-delivery groups. Using the simulated estimates, the mean total costs across the three service-delivery models were compared using paired t-tests to determine relative cost efficiency of the models. A secondary exploratory analysis was then undertaken using the same statistical methods, though with a change to the modelling to reflect costs if all participants received the Therabite™ device. This was conducted as the use of the Therabite™ for jaw rehabilitation with patients with HNC has now become increasingly recognised internationally as a new standard of care, since the commencement of the study [42–44].

Following comparison of total costs, a cost effectiveness analysis was conducted. The mean differences in AQoL-6D scores between the two time-points (baseline and end of (C)RT) for each service-delivery group, and between groups, were analysed using paired t-tests. A p value < 0.05 was considered statistically significant. In addition to statistical significance, the AQoL-6D data were also interpreted for *clinical significance*, which is indicated by a 0.05 or greater change in scores [45, 46]. Cost-effectiveness was then considered for any comparison which was found to have either a statistical or clinical difference in QoL between groups. Where this difference occurred, an incremental cost-effectiveness ratio (ICER) was estimated. An ICER offsets the difference in costs associated with two interventions by their relative potential benefits in QoL (measured in QALYs). The dollar cost per QALY was then evaluated relative to the widely accepted willingness-to-pay threshold of $50,000/QALY [47]. Interventions with ICERs that fall below this threshold are considered to be good value for money.

Table 3 Breakdown of simulation for total costs of each service-delivery model

Type of cost	Service-delivery model		
	SwallowIT	Clinician-directed	Patient-directed
Health-service costs			
Pre-treatment education	✔	✔	✔
Weekly SLP/DN session	✔	✔	✔
(early + late (C)RT, clinician time + consumables)	× 6	× 6	× 6
	(3 × early, 3 × late)	(3 × early, 3 × late)	(3 × early, 3 × late)
SLP-directed prophylactic swallowing therapy sessions	N/A	✔	N/A
		× 30	
Therapy resources			
Therabite™	✔	✔	N/A
Tongue depressors	N/A	N/A	✔
Telepractice equipment	✔	N/A	N/A
Patient-attributable costs			
Patient time per session	✔	✔	✔
	× 6 (SLP/DN sessions only)	× 30	× 6 (SLP/DN sessions only)

Results

Enrolment began September 2013 and ended December 2015. During this time, 79 participants were recruited. Two participants withdrew from the study before beginning the prophylactic swallowing exercise protocol, and two participants withdrew during the therapy period, leaving a cohort of 75 participants (Fig. 2). The majority were males aged in their late 50s receiving radiotherapy with adjuvant systemic therapy for locally advanced oropharyngeal SCC (Table 4). The three study arms were comparable with respect to all key baseline demographics (Table 4).

Health Service Costs

The largest cost component for all models of care was SLP/DN service costs (Table 5). The *SwallowIT* model required substantially less SLP contact time than the clinician-directed model translating to a health service cost saving of $990 per patient. Clinical contact time for *SwallowIT* and patient-directed models were the same. The total cost for consumables were comparable between the three service models. The *SwallowIT* model required additional therapy resources to both the patient-directed and clinician-directed models in the form of the telepractice equipment. This was an additional cost of $54.30 per patient (tablet, internet,

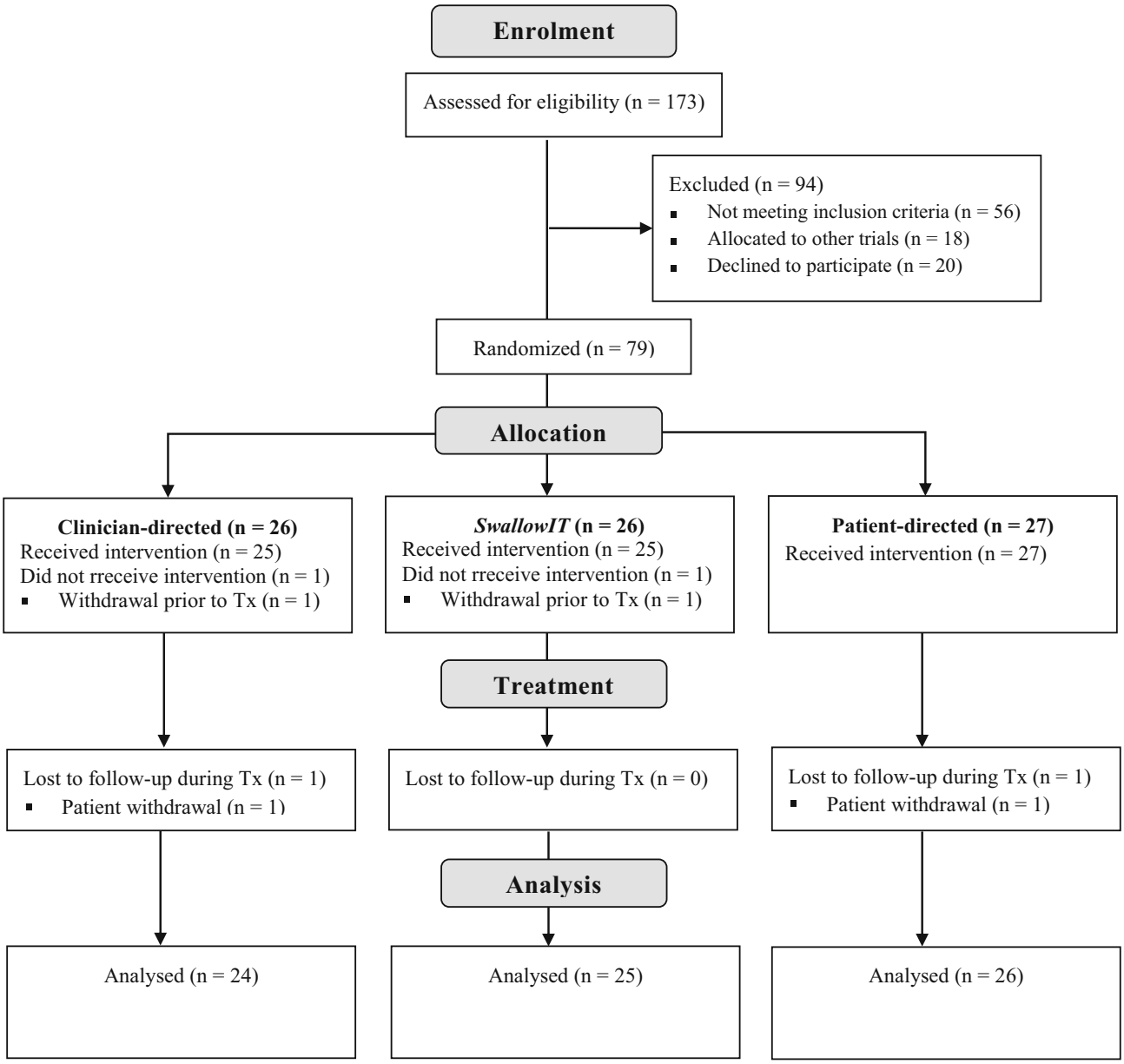

Fig. 2 CONSORT flow diagram

Table 4 Demographic details of participant cohort ($n = 75$)

Parameter	*SwallowIT* $n = 25$ % (n)	Clinician-Directed $n = 24$ % (n)	Patient-Directed $n = 26$ % (n)	Total $N = 75$ % (n)	p
Age	M = 59.80 years	M = 59.00 years	M = 56.92 years	M = 58.55 years	0.457[b]
	SD = 7.37 years	SD = 6.67 years	SD = 10.58 years	SD = 8.41 years	
Gender					
Male	92 (23)	92 (22)	85 (22)	89 (67)	0.719[c]
Female	8 (2)	8 (2)	15 (4)	11 (8)	
T stage					
0	8 (2)	8 (2)	12 (3)	9 (7)	0.551[c]
1–2	64 (16)	46 (11)	42 (11)	51 (38)	
3–4	28 (7)	46 (11)	46 (12)	40 (30)	
N stage					
0	12 (3)	13 (3)	8 (2)	11 (8)	0.578[c]
1	8 (2)	8 (2)	23 (6)	13 (10)	
2–3	80 (20)	79 (19)	69 (18)	76 (57)	
Treatment modality					
XRT only	8 (2)	13 (3)	8 (2)	9 (7)	0.788[c]
CRT	92 (23)	87 (21)	92 (24)	91 (68)	
Socioeconomic status[a]	Median = 7	Median = 7	Median = 8	Median = 7	0.394[d]
	(range 1–10)	(range 1–10)	(range 1–10)	(range 1–10)	

[a]Australian Bureau of Statistics Socio-Economic Indexes for Areas—national population decile (Index of Relative Advantage and Disadvantage) based on geographical location of residence 1 = most disadvantaged, 10 = most advantaged

[b]One-way ANOVA used

[c]Fisher's Exact test used

[d]Kruskal–Wallis H test used

Table 5 Total cost comparison by service-delivery model incorporating health-service and patient-attributable costs

Costs	*SwallowIT*	Clinician-directed	Patient-directed	
			Current model	Model + Therabite™
Component costs				
Total service costs	$728.75	$1757.75	$728.75	$728.75
Total consumables/therapy resource costs	$652.73	$598.43	$102.63	$598.43
Total patient time/wages costs	$231.60	$1158.00	$231.60	$231.60
Overall costs				
Overall health system costs	$1381.48	$2356.18	$831.38	$1327.18
Overall patient-attributable costs	$231.60	$1158.00	$231.60	$231.60
Overall health system costs + patient-attributable costs	**$1613.08**	**$3514.18**	**$1062.98**	**$1558.78**

Bold type indicates statistical significance. Difference between *SwallowIT* and patient-directed significant (t test; $p < 0.05$), difference between *SwallowIT* and clinician-directed significant (t test; $p < 0.05$)

application cost). Both clinician-directed and *SwallowIT* models required the costs of the Therabite™ ($500) compared to the patient-directed model.

Patient-Attributable Costs

The average patient travel cost to MSROS was calculated to be $97.20 per session, and a further $38.60 per session in lost time/wages. The *SwallowIT* model provided

substantial cost savings for patients in terms of waiting time compared to the clinician-directed model, with a $926.40 per patient difference in opportunity costs (Table 5). The *SwallowIT* model provided identical patient-attributable costs to the patient-directed model.

Overall Cost Analysis

Considering all costs (Table 5), there were statistically significant differences between the service-delivery models. The *SwallowIT* model was significantly ($p < 0.001$; 95% CI $1874.08, $1959.92) cheaper to provide than the clinician-directed model, with an overall cost saving of $1901.10 per patient. Based on the current study procedure (patient-directed model using tongue depressors rather than a Therabite™), the *SwallowIT* model was significantly ($p < 0.001$; 95%CI $523.05, $566.95) more expensive than the patient-directed model, in the order of $550.10 per patient. However, when modifying the estimates to include Therabite™ costs in all groups, the *SwallowIT* model was still significantly ($p < 0.001$; 95%CI $53.24, $56.76) more expensive than patient-directed; however, the absolute difference was only $54.30.

Health-Related Quality of Life

Within-group analysis revealed a statistically significant reduction in patients' reported health-related QoL in all groups between baseline and end of (C)RT (Table 6). Between-group analysis revealed no statistically significant difference in the extent of AQoL-6D utility score change between the service models (ANOVA: $F = 1.60$, $p = 0.2107$) (Table 6). However, when examining the data for *clinical significance*, both the *SwallowIT* and clinician-directed models had > 0.05 higher utility scores (i.e. clinically superior QoL) than the patient-directed group at the end of (C)RT. There were no clinically significant differences observed between the *SwallowIT* and clinician-directed models.

Cost-Effectiveness Analysis

As *SwallowIT* yielded a clinically significant difference in health-related QoL compared to patient-directed therapy at the end of (C)RT, a cost-effectiveness analysis was conducted between the *SwallowIT* and patient-directed models. The estimated ICER between *SwallowIT* and patient-directed therapy (based on patient-directed using tongue depressors) was $6220/QALY. When applied to the simulation where all patients received a Therabite™ this became $404/QALY. Therefore, compared to the patient-directed model, the *SwallowIT* model can be described as cost-effective, providing improved outcomes at an acceptable cost (below the willingness-to-pay threshold of $50,000 per QALY [47].

Cost-effectiveness analyses were unable to be conducted between the *SwallowIT* and clinician-directed models, as there were no statistically or clinically significant differences in QoL scores between the two models. Instead, compared to the clinician directed model, the *SwallowIT* model can only be described as cost-efficient. That is, there was no clinically or statistically significant difference in health-related QoL between the two models, but the *SwallowIT* model was associated with a statistically significant reduction in cost.

Discussion

In an era of value-driven health care, comprehensive economic evaluation of any new service-delivery model against current best practice and/or standard care practices

Table 6 Health-related Quality of Life (AQoL-6D) utility scores by service-delivery model (within- and between-group differences)

	Pre-(C)RT M (SD)	End of (C)RT M (SD)	Within-group Mean difference (p value)
SwallowIT	0.830 (0.16)	0.619 (0.14)	**− 0.211 ($p < 0.001$)**
Clinician-directed	0.797 (0.17)	0.605 (0.19)	**− 0.192 ($p < 0.001$)**
Patient-directed	0.819 (0.13)	0.522 (0.21)	**− 0.297 ($p < 0.001$)**
Between-group mean difference (p-value)			
SwallowIT versus clinician-directed	0.033 ($p = 0.522$)	0.014 ($p = 0.786$)	
SwallowIT versus patient-directed	0.011 ($p = 0.851$)	0.097* ($p = 0.102$)	
Clinician-directed versus patient-directed	− 0.022 ($p = 0.698$)	0.083* ($p = 0.193$)	

Bold type indicates statistical significance

*Denotes clinically significant score change

is crucial to ensure the new model either: (a) improves outcomes at a reasonable cost or (b) lowers costs without compromising outcomes [10, 12]. This is a unique study comparing the health service and patient-attributable costs of delivering a prophylactic swallowing therapy program to patients with HNC via three alternative models of care. It is also the first known study to investigate the costs and cost-effectiveness of using an asynchronous telepractice application to provide dysphagia therapy. *SwallowIT* provided a more cost-efficient model of care than clinician-directed (equivalent outcomes at reduced cost), and greater cost-effectiveness than the patient-directed model (improved outcomes achieved at an acceptable cost).

The current findings have demonstrated that the *SwallowIT* model of care was comparable in costs to the patient-directed model (when modelled for all patients receiving a Therabite), however provided significant cost savings when compared to a clinician-directed model, translating to a 42% cost saving ($1901.10 per patient) for the health service when using *SwallowIT*. This primarily stemmed from the reduction in SLP contact time, as daily FTF clinician-directed sessions were replaced with supported home-practice provided by the *SwallowIT* application. International studies have demonstrated that there are currently limited specialist SLP services available to deliver comprehensive intervention to patients with HNC, and that institutional constraints (i.e. staffing and funding) are major barriers in providing optimal and evidence-based levels of service for patients with HNC [21–23]. Therefore, the ability for the *SwallowIT* model to alleviate burden on staff/service time, whilst still providing patients with remote support for their therapy in the home, at an adherence level commensurate with the FTF protocol [48], has great potential in terms of clinical utility.

Similarly, patient-attributable costs were lower in the *SwallowIT* model compared to clinician-directed therapy, and equivalent to the patient-directed model. This was due to a reduction in patients' waiting time/overall time spent at MSROS, which would have been required when attending daily FTF therapy sessions, as per the clinician-directed model. This is particularly poignant in the HNC population, as it is acknowledged that patients experience significant treatment burden, both in the form of treatment-related side-effects [49, 50], as well as considerable disruption to daily life associated with intensive (C)RT treatment schedules [24, 25]. Thus, the current findings suggest that the functionality of *SwallowIT* to provide convenient and flexible home-based therapy can translate into cost-benefits beyond the health service, and positively impact patients' experiences during HNC treatment.

Based on total cost comparisons (i.e. health service + patient-attributable costs), the *SwallowIT* model was ultimately found to be more *cost-efficient* than the clinician-directed model, as it yielded comparable health-related QoL outcomes for significantly less money (a saving of $1901.10 per patient on average). When extrapolating these cost savings to consider the number of patients who will receive treatment for oropharyngeal HNC in 2016, and are therefore eligible to receive prophylactic swallowing therapy, this translates to a potential saving of over $7 million in Australia, £8.3 million in the UK, and $70.4 million in the USA if all patients were provided with *SwallowIT* instead of clinician-directed therapy [51–53].

Although the *SwallowIT* model was slightly more expensive to provide than the patient-directed model in absolute costs, it was found to be more *cost-effective*. *S*imilar to the clinician-directed model, *SwallowIT* yielded less decrement in health-related QoL at the end of (C)RT compared to the patient-directed model. Although this difference was not statistically significant, it was above the minimum score change of 0.05 considered to be clinically significant [46]. Based on the model where the Therabite™ was provided to all patients, the cost-effectiveness ratio was $404/QALY, which is well below the accepted willingness-to-pay threshold of $50,000/QALY [47]. This suggests that the gain in health-related QoL produced by the *SwallowIT* model, compared to patient-directed therapy, represents good value for money.

Some limitations do exist in this study. Firstly, whilst somewhat mitigated by the use of an adjusted hypothetical cost model, it is acknowledged that the use of tongue-depressors in the patient-directed group (reflecting "usual care" at the time of the study) did introduce deviation in the therapy protocol between the treatment arms, confounding direct between-group cost comparisons. Secondly, health-related QoL data were only analysed at baseline and end of (C)RT. Whilst findings suggested a clinically meaningful difference in health-related QoL scores across these time-points, it is undetermined whether this difference was sustained further into patients' recovery. Future research would benefit from extended long-term follow-up, in order to provide more rigorous data for cost-effectiveness analysis. Thirdly, the study had a modest sample size for economic modelling, and was conducted at a single Australian public hospital site. It is acknowledged that the results may differ in other services where there is a fee-for-service model (e.g. private health services, international models of healthcare) where changes in activity could have different impacts on service outcomes and costs. Finally, cost modelling in the current study was estimated based on patient and clinician survey data, rather than micro-costing per occasion of service. Using a bottom-up approach may have yielded different absolute cost values compared with the average estimates applied in the current study.

Conclusion

The results of the current study demonstrate that *SwallowIT* provided a cost-efficient and cost-effective service-model for the delivery of prophylactic swallowing therapy during (C)RT. *SwallowIT* yielded equivalent health-related QoL outcomes to the clinician-directed model, whilst significantly reducing costs and burden to both the health service and to consumers; and yielded clinically superior health-related QoL outcomes to the patient-directed model, for minimal additional costs. Collectively these findings suggest that *SwallowIT* is economically viable, and may provide a more clinically sustainable method for supporting patients with oropharyngeal HNC to complete intensive, prophylactic swallowing therapy in the future.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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