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HEAD AND NECK

A cost-effectiveness analysis of using TheraBite in a preventive exercise program for patients with advanced head and neck cancer treated with concomitant chemo-radiotherapy

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Abstract Previous studies have shown that a "Preventive Exercise Program" (PREP) is cost-effective compared to the standard exercise program provided in "Usual Care" (UC) in patients with advanced head and neck cancer. The current paper specifically estimates the cost-effectiveness of the TheraBite jaw rehabilitation device (TB) which is used as part of the PREP, compared to Speech Language Pathology (SLP) sessions as part of UC, and herewith intents to inform reimbursement discussions regarding the TheraBite device. Costs and outcomes [quality-adjusted life-years (QALYs)] of the TB compared to SLP were estimated using a Markov model of advanced head and neck cancer patients. Secondary outcome variables were trismus, feeding substitutes, facial pain, and pneumonia. The incremental cost-effectiveness ratio (ICER) was estimated from a health care perspective of the Netherlands, with a time horizon of 2 years. The total health care costs per patient were estimated to amount to €5,129 for the TB strategy and €6,915 for the SLP strategy. Based on the current data, the TB strategy yielded more quality-adjusted life-years (1.28) compared to the SLP strategy (1.24). Thus, the TB strategy seems more effective (+0.04) and less costly (−€1,786) than the SLP only strategy. At the prevailing threshold of €20,000/QALY the probability for the TB strategy being cost-effective compared to SLP was 70 %. To conclude, analysis of presently available data indicates that TB is expected to be cost-effective compared to SLP in a preventive exercise program for concomitant chemo-radiotherapy for advanced head and neck cancer patients.

Keywords Head and neck cancer · Concomitant chemo-radiotherapy · Cost-effectiveness · Rehabilitation · TheraBite · Prophylactic dysphagia exercise programs

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Background

Concomitant chemo-radiation for treatment of advanced head and neck cancer can cause severe complications such as dysphagia and trismus, with substantial deterioration of patients' quality of life. These function impairments can be severe and long lasting, and have received not only special attention in therapeutic, but also more recently in preventive settings [1, 2]. Trismus has been reported to be already present in 2 % of all newly diagnosed patients, and additionally to be induced through surgery or radiotherapy in 8 % of patients [3, 4]. The prevalence in the literature varies from 5 to 38 % [5], which is largely attributed to the use of different norms to define trismus. These range from 18 mm and less to 40 mm and less. Trismus negatively impacts oral intake, hygiene, chewing, and swallowing [6]. Difficulty in maintaining adequate nutrition and oral health are other issues that have been linked to trismus in addition to deterioration of pulmonary function [7].

The TheraBite® Jaw Motion Rehabilitation System™ is a frequently used device, which has proven its effectiveness in both preventive and treatment settings for trismus [1, 2, 8–10]. Furthermore, this device is also used to perform the 'Open Swallow Exercise', which is intended to improve or maintain hyolaryngeal elevation [2, 11].

While the preventive advantages of TheraBite are well known, also in the long term, further information regarding costs and cost-effectiveness (short and long term) of this preventive strategy is desirable [1, 10]. In a recent publication from the same research group of the current paper, the cost-effectiveness of a preventive (swallowing) exercise program (PREP) in general was compared to a standard exercise program (usual care (UC)) [12]. For that cost-effectiveness study, 1-year follow-up data of the program in the Netherlands Cancer Institute were used. The study concluded that PREP was cost-effective compared to UC.

However, the long-term cost-effectiveness of PREP is still unknown and in particular, the question remains whether the additional costs for the TheraBite device in this PREP are justified. Therefore, the objective of the current paper is to compare the TheraBite device versus Speech Language Pathology (SLP) sessions alone (in this case protocolled swallowing exercises given and monitored by a speech language pathologist (SLP)) in the preventive setting of advanced head and neck cancer patients treated with concomitant chemo-radiotherapy, with a follow-up of 2 years.

Materials and methods

Case description

We investigated the cost-effectiveness of the TheraBite® (TB) as part of the preventive exercise program (PREP) versus Speech Language Pathology (SLP) sessions included in a standard preventive exercise program (UC) in advanced head and neck cancer patients.

Data of a preventive exercise study in the Netherlands Cancer Institute were used [13]. The protocol was approved by the Protocol Review Board of the Netherlands Cancer Institute-Antoni van Leeuwenhoek (NKI-AVL) and written informed consent was obtained from all patients before entering the study.

All patients had advanced (stage III and IV) functional or anatomical inoperable head and neck cancer. All received concomitant chemo-radiotherapy (CCRT), which consisted of 100-mg/m^2 Cisplatin as a 40-min intravenous (IV) infusion on days 1, 22, 43 and combined with radiotherapy, and comparable intensive supportive care. Details about patients, methods, and clinical results in both studies have been published previously [2, 14, 15]. The patient characteristics are summarized in Table 1.

In the preventive exercise study, the effects of preventive strength and stretch exercises on (long-term) swallowing and/or mouth opening problems caused by CCRT were assessed in 55 advanced head and neck cancer patients [13]. Before treatment, all patients were randomized into two groups: an experimental group that was provided with the TheraBite® Jaw Motion Rehabilitation System™ (TB), and a group receiving Usual Care (UC) including standard exercises such as protocolled swallowing exercises. The rationale and a detailed description of the exercises have been published previously [2]. In short, both regimens consisted of comparable stretch and strength exercises to keep the swallowing and mastication musculature active before, during, and after CCRT, even when patients were fed via a (naso)gastric tube. Patients were encouraged to practice three times a day and to integrate the exercises into other daily activities at home. Participants were provided with verbal and written instructions prior to treatment, at which time they also started practicing. At this time, oral intake was not yet influenced by the treatment. During and after treatment, both groups were equally (frequent) monitored by the SLP. At 2-year follow-up, 29 of the 55 included patients were still alive and disease free.

Outcome variables of interest for this cost-effectiveness analysis was presence of trismus, score on the Functional Oral Intake Scale (FOIS; range from 1–7 with 1 = nothing by mouth to 7 = total oral diet with no restrictions), presence of aspiration, and facial pain, see Table 2. In case of aspiration, we assumed that 50 % of the patients would be admitted to the hospital with pneumonia for an average of 4 days. Weight loss was a variable in the preventive exercise study, but as weight only has an indirect effect on costs, it was not considered in the cost-effectiveness analysis.

Table 1 Patient characteristics

	SLP $N = 14$	TheraBite $N = 15$
Patient characteristics		
Age in years		
Median	62.5	57
Range	45–75	39–77
Sex		
Male	9	14
Female	5	1
Stage distribution (%)		
III	6 (43)	5 (33)
IV	8 (57)	10 (67)
Tumor site (%)		
Oral cavity/oropharynx	7 (50)	7 (47)
Hypopharynx	5 (36)	5 (33)
Nasopharynx	2 (14)	3 (20)
Follow-up in months		
Mean (SD)	27 (2.4)	27 (3.1)
Median (range)	26 (24–32)	27 (23–36)
Complaints 2 years after CCRT		
FOIS (scale 0–7)		
<5 (indication for feeding substitutes) "total oral diet, but requiring special preparation or compensations"	1 (7)	0 (0)
Trismus		
Number of patients (%)	2 (14)	0 (0)
Pain VAS scale (0–100 mm)		
Mean (SD)	5.8 (15.6)	0.7 (1.8)
Median (range)	0 (0–54)	0 (0–5)
Aspiration (%)		
2-year after CCRT	1 (7)	0 (0)

Cost-effectiveness analysis

Cost-effectiveness analysis (CEA) is a form of health economic analysis that compares the relative costs and outcomes (effects) of two or more courses of action. Cost refers to the resources used for the intervention and its consequences, usually measured in monetary terms such as dollars or euros. The measure of effects depends on the intervention being considered. The selection of the appropriate effect measure should be based on clinical judgment in the context of the intervention being considered. The most commonly used outcome measure is quality-adjusted life-years (QALY), measured by utilities [16]. Utilities are specifically designed for individual decision-making under uncertainty, but, with additional assumptions, utilities can be aggregated across individuals to provide a group utility function. QALYs are designed to aggregate in a single summary measure the total health improvement for a group of individuals, capturing improvements from impacts on both quantity of life and health-related quality of life. Utilities can be used as the quality-adjustment weights for QALYs; they are particularly appropriate for that purpose, and this combination provides a powerful and highly useful variation on cost-effectiveness analysis known as cost-utility analysis [17]. When cost-effectiveness is based on retrospective data and using various data sources, often a decision model is applied.

Model description

A Markov decision model was developed to compare the TheraBite® (TB) strategy versus Speech Language Pathologist (SLP) strategy with supervised swallowing exercises for prevention of swallowing problems in advanced head and neck cancer patients treated with concomitant chemo-radiation therapy (CCRT). The model was constructed with three mutually exclusive health states: "complete remission", "recurrent disease" and "death" (death of cancer or other causes) (See Fig. 1). The input regarding treatment success rates, and probability of recurrence were based on the published outcome data from our institute [15]. We assumed that the use of TheraBite® had no direct influence on survival [18–20].

The model simulated the course of events in a hypothetical cohort of 1,000 patients aged 55 years with a stage III or IV squamous cell carcinoma of the head and neck treated with CCRT at the NKI-AVL. Possible complications from the treatment were modeled up to 2 years from the start of treatment. The cycle length of the model was one month (a period where certain costs or outcomes can appear, reflecting the underlying natural history of the disease), with a total simulated time horizon of 2 years. The analysis was performed from the health care perspective of the Netherlands. All costs were reported in year 2014 Euros (see Table 2).

Costs

The health professional consultation costs and trismus treatment were derived from the Dutch guidelines for economic evaluations in Health Care [21]. The variables for trismus treatment were derived from a protocol used in the NKI-AVL, including outpatient clinic appointments: 1 × physician, 1 × dentist, 4 × physiotherapist/SLP, 2 × dental hygienist and TheraBite [in 50 % of the cases (for the patients of the SLP strategy, who did not have the TheraBite)]. In very rare cases, patients need surgery to solve trismus; however, this was not taken into account for this patient group and thus not included as a variable in the analysis. The costs of feeding substitutes were obtained

Table 2 Input parameters of base case and sensitivity analysis, including days of feeding substitutes, aspiration probabilities, utilities and costs

Parameters	Mean	SE	Distribution	Source
Survival probabilities				
DFS to DFS	0.983	0.030	Beta	[15]
DFS to DM	0.009	0.001	Beta	[15]
DFS to death	0.008	0.001	Beta	[15]
DM to DM	0.992	0.030	Beta	[15]
DM to death	0.008	0.001	Beta	[15]
Death	1.000	0.030	Beta	
Parameters	Mean	Units	Distribution	Source
Probabilities				
Trismus TB	0.001	0 out of 15	Uniform	[13]
Trismus SLP	0.167	2 out of 14	Uniform	[13]
Feeding substitutes TB	0.067	0 out of 15	Uniform	[13]
Feeding substitutes SLP	0.143	1 out of 14	Uniform	[13]
Pulmonary infections TB	0.001	0 out of 14	Uniform	[13]
Pulmonary infection SLP	0.036	1 out of 14[a]	Uniform	[13]
Facial pain TB	0.007		Uniform	[13]
Facial pain SLP	0.058		Uniform	[13]
Parameters	Mean	SE	Distribution	Source
Utilities				
DFS period	0.880	0.015	Beta	[32]
Palliative period	0.720	0.015	Beta	[32]
Utility decrements				
Pneumonia	0.600	0.015	Beta	Assumption
Feeding substitutes	0.470	0.015	Beta	[25]
Trismus	0.500	0.015	Beta	[29]
Costs in euros				
Pneumonia-total	**2,859.00**	↑↓25 %	Gamma	[21]
Hospital admission (*4)	**618.00**	↑↓25 %	Gamma	[21]
Antibiotics	**85.00**	↑↓25 %	Gamma	[21]
X-ray	**50.00**	↑↓25 %	Gamma	[21]
Trismus-total	**780.40**	↑↓25 %	Gamma	[21]
Consultation physician	**136.00**	↑↓25 %	Gamma	[21]
Consultation dentist	**136.00**	↑↓25 %	Gamma	[21]
Consultation dental hygienist (*2)	**66.00**	↑↓25 %	Gamma	[21]
Consultation physiotherapist/SLP (*4)	**138.00**	↑↓25 %	Gamma	[21]
Pain medication	**85.00**	↑↓25 %	Gamma	[21]
TheraBite (50 %)	**219.40**	↑↓25 %	Gamma	Atos
Feeding substitutes	**1,027.43**	↑↓25 %	Gamma	NKI, [22]
Pain medication (home)	**292.00**	↑↓25 %	Gamma	[21]
TheraBite-total	**702.80**	↑↓25 %	Gamma	[21]
Consultations SLP before treatment (*1)	**33.00**	↑↓25 %	Gamma	[21]
During treatment (*3)	**99.00**	↑↓25 %	Gamma	[21]
After treatment (*4)	**132.00**	↑↓25 %	Gamma	[21]
TheraBite device+ BitePads (*2)	**438.80**	↑↓25 %	Gamma	Atos
SLP-total	**363.00**	↑↓25 %	Gamma	[21]
Consultations SLP before treatment (*1)	**33.00**	↑↓25 %	Gamma	[21]

Table 2 continued

Parameters	Mean	SE	Distribution	Source
During treatment (*3)	**99.00**	↑↓25 %	Gamma	[21]
After treatment (*7)	**231.00**	↑↓25 %	Gamma	[21]

Total of the numbers are in bold

SE standard error, *DFS* disease free survival, *DM* distant metastasis, *TB* TheraBite strategy, *RADPLAT* radiotherapy and concomitant intra-arterial cisplatin, *SLP* speech language pathology

[a] Assuming 50 % of the patients with aspiration develops pneumonia

from the NKI-AVL purchasing department and website of "Sorgente" [22]. Because the need for feeding substitutes was determined for every patient individually (no guideline), it was assumed that of the patients scoring <5 on the FOIS scale, 2/3 needed feeding substitutes or supplements (3 times per day), and 1/3 needed tube feeding for in total 10 weeks. The costs of pneumonia (assumed in 50 % of the aspiration cases) included hospitalization (average 4 days, assumption) and antibiotics (average of most common used medication). The costs of pain medication concerning facial pain were derived from the Dutch pharmacology website: www.medicijnkosten.nl. Finally, the costs of the TheraBite® device were derived from Atos Medical BV, the Netherlands (see Table 2), including BitePads for maintenance. The costs for CCRT, being identical in both rehabilitation strategies, were not included in this analysis, in contrast to our former CEA, where CCRT was part of the preventive exercise program [12].

Health effects

Health-related quality of life was modeled by assigning utilities to the different health states. The utilities are expressed in QALYs. The QALY is a measure of disease burden, including both the quality and the quantity of life lived, where a correction factor (utility weight) is added to the additional life-years lived. The utilities were based on the literature [23–25], because utilities were not measured in the preventive exercise study.

Analysis

The model was programmed in Microsoft Excel (Microsoft, Redmond, WA) and validated using various sensitivity analyses. Future costs and effects were discounted to their present value by a rate of 4 and 1.5 % per year, respectively, according to Dutch pharmacoeconomic guidelines [21]. Incremental cost-effectiveness ratios (ICERS) were calculated by dividing the incremental costs by incremental QALYs. Stochastic uncertainty in the input parameters was handled probabilistically, by assigning distributions to parameters (Table 2) [26]. Parameter values were drawn randomly from the assigned distributions, using Monte Carlo simulation with 5,000 iterations. In general, transition probabilities and utilities were assigned with beta distributions, costs with gamma distributions. Because the number of patients included in the preventive exercise study that served as input to this CEA was quite small, we used uniform distributions for the probabilities of trismus, feeding substitutes and facial pain.

The results of the simulation of the hypothetical cohort of 1,000 patients are illustrated in a cost-effectiveness (CE) plane; each quadrant indicates whether a strategy is more or less expensive and more or less effective [27]. Cost-effectiveness acceptability curves (CEACs) to show decision uncertainty are presented. CEACs show the probability that a pathway has the highest net monetary benefit, and thus is deemed cost-effective, for a range of Willingness to Pay (λ) values for one additional QALY, also referred as the ceiling ratio. This definition involves a Bayesian definition of probability, i.e., the probability that the hypothesis ('The TB strategy is cost-effective compared to the SLP strategy') is true given the data. The two curves, therefore, always sum to 100 % for one given value of λ [28]. In the Netherlands, an informal ceiling ratio of €20,000 per QALY exists for preventive care programs (Dutch Council for Public Health and Health Care 2006).

Sensitivity analyses

We performed one-way sensitivity analyses to test the robustness of the model by changing each individual input parameters—expect the survival data—presented in a Tornado diagram. The costs were varied plus and minus 25 % of the mean, the utilities were varied plus and minus 0.1, the transition probabilities of trismus and feeding substitutes were varied from 0 to 2 extra cases, the range of pneumonia caused by aspiration was varied from 0 to 100 %, and the probability of facial pain was varied with data reported in the literature [29].

Results

Mean results

After 2 years, two patients in the SLP group still experienced trismus, whereas no patients had trismus in the TB

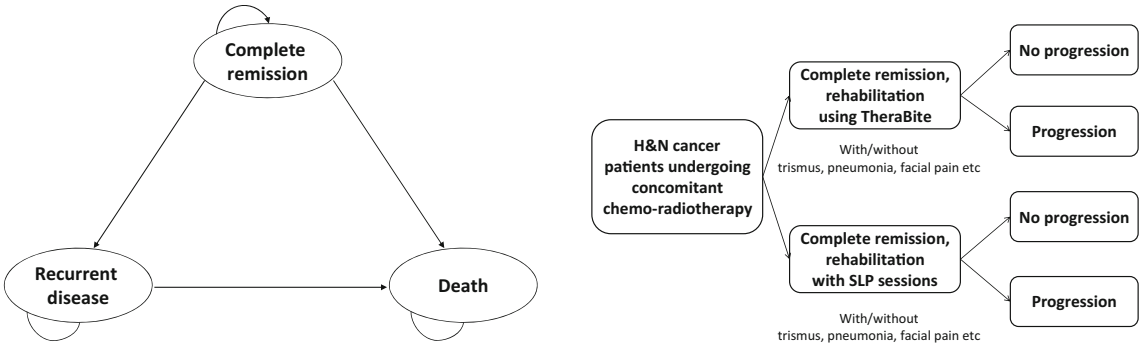


Fig. 1 Model structure and decision tree

group. One patient in the SLP group had a score <5 on the FOIS scale ("total oral diet, but requiring special preparation or compensations"), compared to none in the TB group, where all patients had "total oral diet, with no restrictions". No patients in the TB group experienced aspiration after 2 years, 1 patient in the SLP group did. (See Table 1) Together with the TheraBite device and SLP sessions, these variables lead to the total health care costs of € 5,129 per patient for the TB strategy and €6,915 for the SLP strategy (see Table 3). The TB strategy yielded more quality-adjusted life-years (1.28) compared to SLP (1.24).

Uncertainty analyses

Based on the current data, the ICER indicates that the TB strategy dominates (i.e., is less costly and more effective than UC. The expected difference in costs is −€1,786 and the expected difference in effects is 0.04 QALYs. (See Fig. 2). The scatter plot demonstrates the mean differences in costs and outcomes from the data using 5,000 bootstrap replicates.

Figure 3 shows that the probability of the TB strategy being cost-effective at a threshold of €20,000/QALY was 70 % percent, which indicates that there remains a considerable amount of decision uncertainty.

Sensitivity analyses

Overall, varying each individual parameter across its predetermined range did not change the conclusion that TB dominates UC. Some parameters had more impact on the absolute model outcomes than others though, with transition probabilities of trismus and pneumonia having the largest impact, see Fig. 4.

Discussion

This study showed that the use of the TheraBite Jaw Mobilization as part of a preventive swallowing exercise program in Dutch head and neck cancer patients undergoing chemo-radiation is probably more cost-effective than purely SLP sessions as part of a standard exercise program.

Although in some studies the (significant) differences in effect between a standard exercise program and a program where the TheraBite is used seem small [10, 13], incorporating costs can alter this picture. In the sensitivity analysis, we saw that the probability of trismus and pneumonia had the highest impact on the cost-effectiveness, which means that if the TheraBite device can prevent trismus and pneumonia in even small numbers, it saves the society a substantial amount of money. Herewith, TheraBite is a valuable and cost-effective device to use within a preventive exercise program.

In a previous CEA, we estimated that the incremental cost-effectiveness of a total preventive rehabilitation program lies around €3,200/QALY (more costly, but more effective). In the current analysis, we showed the additional value of TheraBite as part of the preventive exercise program.

As the patients' mouth opening is decreasing and facial pain is increasing, a domino effect takes place, consisting of increase of (pain) medication, health care utilization, and lower HRQoL. These costs are difficult to identify, and this is the first paper, to the best of our knowledge, in which the

Table 3 Results of the base case analysis

	Costs	QALYs	Incremental costs	Incremental QALYS	ICER costs/QALY
TheraBite®	5,129	1.28	−1,786	0.04	DOMINANT[a]
SLP	6,915	1.24			

[a] *DOMINANT* TheraBite program is less costly and more effective compared to the SLP strategy

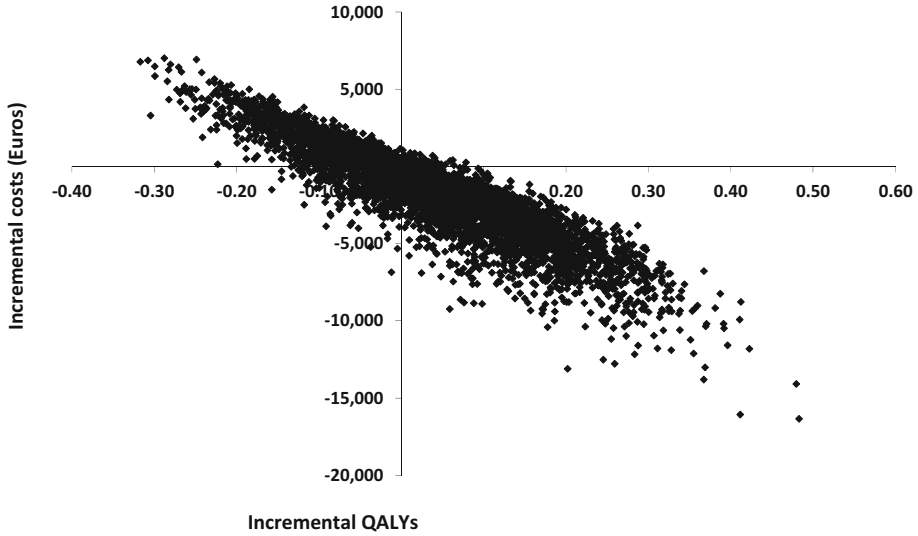


Fig. 2 Cost-effectiveness plane of the quality-adjusted life-years (QALYs) per costs of the TheraBite strategy (TB) versus Speech Language Pathologist (SLP) strategy. The *scatter plot* is showing the mean differences in costs and outcomes from the data using 5,000 bootstrap replicates. Ninety-nine percent of the *dots* are in the South-East quadrant which indicates that the TheraBite strategy is in most cases less expensive and more effective compared to the SLP strategy

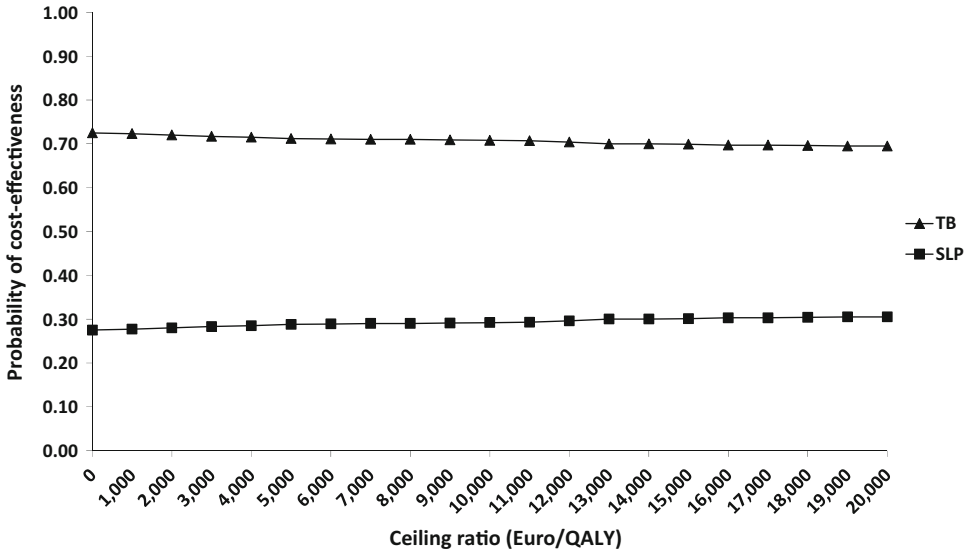
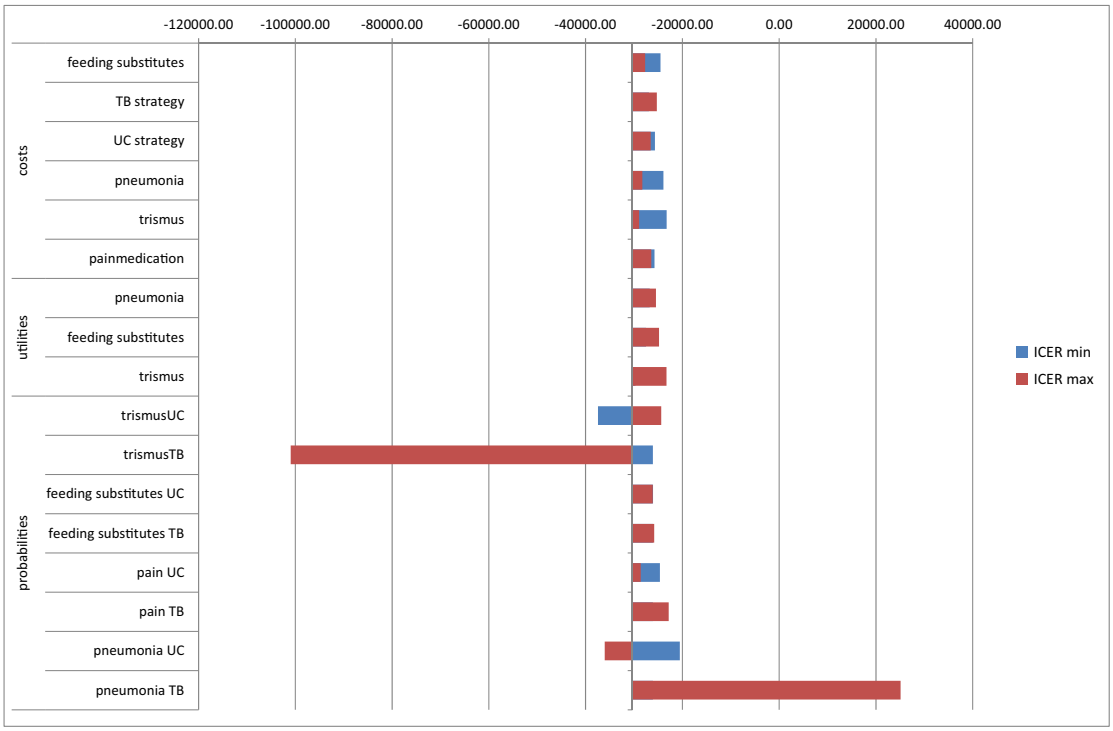


Fig. 3 Base case Cost-effectiveness Acceptability Curves (CEAC); presenting the probability of cost-effectiveness of the two alternatives for a range of values of thresholds

costs are investigated in this respect. Costs for exercise time were not included in the model, because these were negligible in the analysis.

A limitation of this study is that the main data generation was performed with small patient groups. Therefore, there is considerable uncertainty around the adoption decision. This is, however, often the case in this patient category. In this particular study, it was hard to unambiguously attribute specific problems to trismus. Therefore, we performed one-way sensitivity analysis on all parameters, and found that the uncertainty surrounding these did not change the outcome. In our dataset, significantly less weight loss was observed in the TB strategy compared to the SLP strategy, but we were unable to use this directly in the analysis. From Gourin et al. [30], we know that weight loss can lead to higher resource use and thus costs, which could mean that (based on the results of the preventive exercise trial), we might have underestimated our expected cost savings. From Melchers et al. and Pauli et al., we know that compliance towards exercising



Accompanying table: Sensitivity Analyses

Parameters	Mean	min	max	Source
Probabilities				
Trismus TB-group	0.001	0.001	0.250	Assumptions
Trismus SLP-group	0.167	0.001	0.250	Assumptions
Feeding substitutes TB-group	0.067	0.001	0.200	Assumptions
Feeding substitutes SLP-group	0.143	0.001	0.200	Assumptions
Pulmonary infections TB-group	0.001	0.001	0.140	Assumptions
Pulmonary infection SLP-group	0.071	0.001	0.140	Assumptions
Facial pain TB-group	0.007	0.001	0.134	[29]
Facial pain SLP-group	0.058	0.001	0.156	[29]
Utility decrements				
Pneumonia	0.600	0.500	0.700	Assumptions
Feeding substitutes	0.470	0.370	0.570	Assumptions
Trismus	0.500	0.400	0.600	Assumptions
Costs in euros				
Pneumonia-total	2859,00	↑↓25%		[21]
Trismus-total	780,40	↑↓25%		[21]
Feeding substitutes	1027,43	↑↓25%		NKI, [22]
Pain medication (home)	292,00	↑↓25%		[21]
TheraBite-total	702,80	↑↓25%		[21]
SLP-total	636,00	↑↓25%		[21]

Fig. 4 Tornado diagram presenting results of sensitivity analyses

using TheraBite is important to maintain the advantages. Therefore, we incorporated also SLP sessions into the TB strategy [31, 32].

The diversity of complaints is extensively investigated in Health Related Quality of Life assessments, but unfortunately this has not been the case for the utilities. The

utilities used in this study, therefore, were generated from several secondary sources and as a consequence may be too general in nature to capture relevant differences, and also, they are based on a variety of measurements. It would be interesting to perform more research into specific disease-related utilities for this patient group, because head and neck cancer and its consequences are very specific. Finally, as shown in the sensitivity analyses, the probability of trismus and pneumonia had the highest impact on the cost-effectiveness. So, for further research, these parameters are of interest as well.

To conclude, this analysis demonstrated that the preventive use of swallowing and passive motion exercises with the TheraBite jaw mobilization device in a preventive exercise program for patients with advanced head and neck cancer who will be treated with concomitant chemo-radiotherapy is expected to be a cost-effective (less costly and more effective) use of scarce healthcare resources. The TB is a valuable device to use in this patient group, and further studies might be warranted to investigate if this could also be the case for other patient groups.

Conflict of interest V.P. Retèl is part-time employed at the Clinical Affairs department of Atos Medical AB as a Health Economist. All other authors declared no conflicts of interest.

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