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Cost-Effectiveness of Reduced Waiting Time for Head and Neck Cancer Patients due to a Lean Process Redesign

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ABSTRACT

Background: Compared with new technologies, the redesign of care processes is generally considered less attractive to improve patient outcomes. Nevertheless, it might result in better patient outcomes, without further increasing costs. Because early initiation of treatment is of vital importance for patients with head and neck cancer (HNC), these care processes were redesigned. **Objectives:** This study aimed to assess patient outcomes and cost-effectiveness of this redesign. **Methods:** An economic (Markov) model was constructed to evaluate the biopsy process of suspicious lesion under local instead of general anesthesia, and combining computed tomography and positron emission tomography for diagnostics and radiotherapy planning. Patients treated for HNC were included in the model stratified by disease location (larynx, oropharynx, hypopharynx, and oral cavity) and stage (I–II and III–IV). Probabilistic sensitivity analyses were performed. **Results:** Waiting time before treatment start reduced from 5 to 22 days for the included patient groups, resulting in 0.13 to 0.66 additional quality-adjusted life-years. The new workflow was cost-effective for all the included patient groups, using a ceiling ratio of €80,000 or €20,000. For patients treated for tumors located at the larynx and oral cavity, the new workflow resulted in additional quality-adjusted life-years, and costs decreased compared with the regular workflow. The health care payer benefited €14.1 million and €91.5 million, respectively, when individual net monetary benefits were extrapolated to an organizational level and a national level. **Conclusions:** The redesigned care process reduced the waiting time for the treatment of patients with HNC and proved cost-effective. Because care improved, implementation on a wider scale should be considered.

Keywords: cost-effectiveness analysis, economic evaluation, head and neck, process redesign, waiting time.

Introduction

Optimal treatment for every individual patient has always been the main goal in medicine. However, the increased number of costly new treatment options combined with the aging population result in a dramatic increase in health care costs [1,2]. Because resources are scarce, decisions have to be made on which treatment options should be made available for society and included in health care insurance packages. Cost-effectiveness analyses can support these difficult decisions by providing the relevant information including long-term costs and benefits for patients and the health care sector [3].

A redesign intervention of care processes might optimize quality and efficiency of care, although medical professionals often consider it less attractive than adopting new technologies. Time to treatment or waiting time might be shortened, resulting in better patient outcomes without driving costs to a maximum. For oncology patients in general, and for patients with head and neck cancer (HNC) in particular, waiting time is significantly associated with patient outcome. Because HNC tumors have a fast doubling time, long waiting times cause tumor progression and negatively affect local tumor control and survival rates [4]. Based on theoretical evidence, delay in radiotherapy (treatment with irradiation) may affect the outcomes of treatment by permitting the proliferation of clonogenic cells, leading to decreased probabilities of local control, which has been confirmed by retrospective observational studies [5]. Chen et al. [4] showed in a systematic review that the risk of local recurrence (relative risk [RR] 1.15 per month waiting time) and mortality (RR 1.16 per month waiting time) increased for patients with HNC with increased waiting time for radiotherapy. Waaijer et al. [6] estimated an average control loss of 16% to 19% due to tumor progression for a mean waiting time of 56 days, potentially resulting in increased mortality [7]. The probability and severity

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of treatment complications might also increase, because larger volumes have to be irradiated, causing a potential decrease in quality of life for patients [8]. Therefore, optimization of care processes to minimize the waiting time is important to improve outcomes for patients with HNC.

The treatment of patients with HNC needs optimal collaboration between several disciplines (head and neck [HN] surgeons, radiation oncologists, medical oncologists, pathologists, radiologists, etc.) to improve medical decision making. Involving all these disciplines could hamper short waiting times. With an aim to optimize waiting times, we redesigned the care process and evaluated its benefits in terms of patient outcome and cost-effectiveness.

Methods

Markov Model Description

A cost-effectiveness analysis was performed for patients with stage I and II and stage III and IV HNC located in the oropharynx, larynx, hypopharynx, and/or oral cavity, for which the workflow was redesigned. Patients were treated at the Maastricht University Medical Centre and at the MAASTRO CLINIC, in the joint Multidisciplinary Head and Neck Board, including HN surgeons as well as radiation oncologists. These particular patient groups were considered because of the expected benefits on patient outcomes from a shortened time to treatment [4] and the possibilities of redesigning the workflow for these patients in particular. Results were stratified for tumor sites and stages because differences in not only improvements in the waiting time, but also the prognoses and quality of life of these patients groups were expected. The Tumor Nodes Metastases stage grouping system of the Union for International Cancer Control, seventh edition, was used for staging [9]. Stage IV can be further subdivided into stage IVa (based on T4 status), IVb (based on N3 status), and IVc (based on M1, distant metastases). In this study, patients only with locoregional disease, that is, stage I, II, III, IVa, and IVb, were included. Patients with stage IVc (metastasized disease) were excluded.

In the studied organizations, the standard diagnostics of the mentioned patient groups included a computed tomogram or magnetic resonance imaging, an X-thorax, and a tumor biopsy under full anesthesia in an operating theater in accordance with the national guidelines for clinical practice [10]. For patients with HNC treated by radiotherapy, a therapeutic computed tomography-positron emission tomography (PET-CT) is performed for treatment planning. In the regular workflow, this PET-CT is performed after diagnosis within the preparation phase of radiotherapy. To reduce waiting times and use equipment and personnel more efficiently, the workflow of the diagnostic and preparation phases of radiotherapy was redesigned. A Markov model was used to analyze costs and benefits of this logistic process redesign. This redesign included two main organizational changes:

1. Performing a diagnostic tumor biopsy and evaluation of the upper aerogastrointestinal tract under local instead of general anesthesia (time to treatment shortened by 17 days).
2. Performing a diagnostic PET-CT in radiation treatment position using an immobilization mask before radiotherapy instead of an additional PET-CT during preparation for radiotherapy (time to treatment shortened by 5 days).

The rationale for the first change was that the examination under general anesthesia required available time in the operation theater and this proved to be a rate-limiting step in the diagnostic process of patients with HNC. To increase the efficiency of the diagnostic process and decrease waiting times for patients, new methods were evaluated to diagnose HNC without losing the quality of investigation. Chip-on tip cameras provide excellent imaging and are technologically advanced as compared with earlier fiber optic tools [11]. Imaging of the lungs has improved drastically, and is increasingly performed under local anesthesia since the development of these chip-on tip cameras. Because of these positive results combined with the possibility of performing a tumor biopsy under local instead of full anesthesia, a pilot was performed for patients with HNC. Preliminary results from this study show that flexible pan endoscopy under local anesthesia is as good as pan endoscopy under general anesthesia, and in some situations superior, for example, assessment of larynx movements. Although the accuracy of this diagnostic tumor biopsy for HNC using local anesthesia is promising, it is still under consideration.

The rationale for the second change was that staging PET-CT is not standard in the diagnostics of patients with HNC. Usually, locoregional staging is performed by CT and/or magnetic resonance imaging of the HN region in accordance with the national guidelines for clinical practice [10]. Screening for distant metastases is usually done by a conventional chest X-ray (for low-risk patients), or a CT-chest for high-risk patients. PET-CT in treatment position of the HN and the upper thoracic area is not performed in every radiotherapy center for radiation treatment planning of HN tumors. An increasing number of radiotherapy centers (including the studied organization), however, consider PET-CT a standard procedure for treatment planning to facilitate the delineation of the gross tumor volume for particular patient groups [12,13]. Because of the etiological factors associated with HNC (i.e., nicotine and alcohol abuse), these patients are also at risk of secondary tumors, for example, lung cancer and/or esophageal cancer. Performing a PET-CT for radiation treatment planning, therefore, increases the detection of second primary tumors and/or metastases that had not been identified in conventional staging. This would lead to additional investigational procedures and delay the start of treatment. By performing a diagnostic PET-CT of the HN area and the chest in radiation treatment position instead of performing a PET-CT after diagnosis, optimal staging, including screening for second primaries, or metastases, is combined with the preparation for state-of-the-art radiation treatment planning. By including a PET-CT in radiation treatment position in the diagnostic process of patients expected to receive radiotherapy treatment, time to treatment can be reduced and a diagnostic CT becomes unnecessary.

The original/regular process flow (regular workflow [RWF]) was compared with three new process flows (new workflow [NWF]): 1) tumor biopsy (to define tumor status) under local anesthesia. Because local anesthesia can be provided outside of operation theater, scheduling is independent of surgery schedules and delays; 2) a diagnostic PET-CT used before radiotherapy; and 3) a combination of 1) and 2) (see Table 1). Because only the logistics of the workflow changed, the actual care/treatment of the included patients did not, and was still in accordance with the national guidelines for clinical practice [10]. Only patients with tumors located in the larynx and in the oral cavity were considered for a biopsy under local anesthesia, because the other tumors cannot be optimally assessed under local anesthesia because palpation forms a big part of this assessment. Most patients with tumors of the oral cavity are treated with surgery as primary treatment. Postoperative radiation therapy is given on the basis of indications derived from the pathology report. Therefore, these patients were not considered for a PET-CT in radiation treatment position.

The current Markov model used in this study included four health states: progression-free survival, local/regional recurrence

Table 1 – The gained working days due to the new workflow relative to the regular workflow.

Tumor site	Stage	Local anesthesia	Diagnostic PET-CT	Gained waiting time (d)* (expected)	Beta PERT distribution	
					Minimum	Maximum
Larynx	I–II	Yes	Yes	22	10	38
	III–IV	Yes	Yes	22	10	38
Oropharynx	I–II	No	Yes	5	3	10
	III–IV	No	Yes	5	3	10
Hypopharynx	I–II	No	Yes	5	3	10
	III–IV	No	Yes	5	3	10
Oral cavity	I–II	Yes	No	17	7	28
	III–IV	Yes	No	17	7	28

PET-CT, computed tomography-positron emission tomography.
* Waiting time was incorporated in the model using a beta PERT distribution (see above for the expected, minimum, and maximum values).

of the tumor, metastases, and death (Fig. 1). A cycle time of 6 months and a lifetime horizon were used to incorporate most long-term effects.

Model Input Parameters

Actual treatment and diagnoses were equal for the different modalities. The waiting time differed, however, because of deviating process designs. Input parameters of the model are presented in Table 2. Data from a pilot study in the studied organization were used to indicate time gains for each process flow, and were expressed in the number of working days (5 d/wk). A time gain of 22 working days could in reality cover 30 days of waiting time. The most conservative estimation (i.e., shortest time gain) was used for the NWF. In the Markov model, the parameter's uncertainty of waiting time was incorporated by a beta PERT distribution (Table 1). The differing time gains were related to the RRs of 1.16 for death, and metastases, and 1.15 for local/regional recurrence for every month waiting time [4]. Therefore, each tumor location resulted in different transition probabilities between the defined health states. The RRs for the gained time were assumed to be linearly related to the amount of time gained. To obtain the RR associated with 5-day, 17-day, or 22-day reduction in waiting time, the RR for a month was converted to a 1-day reduction multiplied by the time gain per tumor location: 1 + (RR for 1 month 1) × 12/365.5 × time gain. To estimate survival, local/regional recurrence, and metastases for oropharynx and larynx tumors, parametric survival models (exponential and Weibull) were estimated stratified for tumor site and stage. Estimates were based on data retrieved from medical files (period 1965–2012) of 2096 patients with HNC (938 with tumors of the larynx stage I–II and 620 with stage III–IV, and 83 with tumors of the oropharynx stage I–II and 455 with stage III–IV) [14]. Hazard ratios reported by Datema et al. [15] were used to convert transition probabilities for oropharynx tumors to tumors located at the hypopharynx and the oral cavity. These RRs were assumed to be equal for survival, local/regional recurrence, and distant metastases. Toxicity was assumed to be equal for NWF and RWF.

Effects and Costs

Utility scores were combined with life expectancy to calculate quality-adjusted life-years (QALYs). Utility scores provide a single index value for health-related quality of life, ranging from 0 (death) to 1 (optimal health), and were estimated on the basis of EuroQol five-dimensional questionnaire [16]. The disutilities for the health states, local/regional recurrence, and metastases were assumed to be independent of treatment site and disease stage.

Costs were estimated as the costs per health care activity in the studied organizations in 2013 multiplied by the required health care activities on the basis of opinions of clinical experts (Appendix A). Costs that potentially differed between the two logistical processes were mainly focused on because only these costs could influence the incremental cost-effectiveness analysis. Three dimensions of costs were included in the Markov model:

1. *Event costs:* Costs for all the expected health care activities in need incurred when the health state of a patient changed (e.g., a recurrence).
2. *Follow-up (health state) costs:* All follow-up costs for the first 5 years after treatment until the next event. From the sixth year onward, follow-up costs were assumed to be zero.
3. *Intervention costs:* The intervention cost were partly covered by the costs associated with the implementation of the redesign (NWF), which is based on the purchase cost for the endoscope (Pentax chip-on tip) with unit (estimated at €50,000), and spread over 1000 patients to be diagnosed (1250–1400 patients expected in 5 years). The intervention costs also covered the costs for unnecessary activities, which included the costs for patients whose biopsy under local anesthesia failed and an

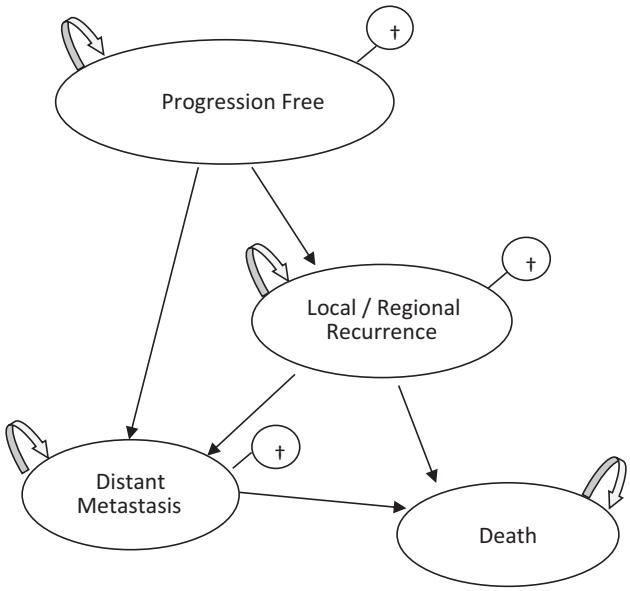

Fig. 1 – Markov model with half-year cycle time and a lifetime span.

Table 2 – Input parameters of Markov model.

Parameter	Estimated value	SE/95% CI	Distribution	Source
Utility score for progression-free state				
Larynx, stage I–II	0.84	0.03	Beta	[14]
Larynx, stage III–IV	0.86	0.02	Beta	[14]
Oropharynx, stage I–II	0.85	0.04	Beta	[14]
Oropharynx, stage III–IV	0.85	0.02	Beta	[14]
Hypopharynx, stage I–II	0.85	0.04	Beta	[14]
Hypopharynx, stage III–IV	0.85	0.02	Beta	[14]
Oral cavity, stage I–II	0.9	0.05	Beta	[14]
Oral cavity, stage III–IV	0.89	0.02	Beta	[14]
Disutility local/regional recurrence, and distant metastasis vs. progression-free survival	0.13	0.07	Beta	[14]
Parameters parametric survival model*				
Larynx, stage I–II				
Mortality (base)	3.5	0.27	Exponential	[12]
Mortality (tumor_site_specific)	1.77	0.46	Exponential	[12]
Mortality (log_scale)	0	0	Exponential	[12]
Local/regional recurrence (base)	1.73	0.4	Weibull	[12]
Local/regional recurrence (tumor_site_specific)	0.76	0.31	Weibull	[12]
Local/regional recurrence (log_scale)	0.32	0.16	Weibull	[12]
Distant metastasis (base)	3.5	0.27	Exponential	[12]
Distant metastasis (tumor_site_specific)	-1.77	0.46	Exponential	[12]
Distant metastasis (log_scale)	0	0	Exponential	[12]
Larynx, stage III–IV				[12]
Mortality (base)	1.8	0.14	Exponential	[12]
Mortality (tumor_site_specific)	-0.78	0.14	Exponential	[12]
Mortality (log_scale)	0	0	Exponential	[12]
Local/regional recurrence (base)	2.04	0.26	Weibull	[12]
Local/regional recurrence (tumor_site_specific)	-1.01	0.21	Weibull	[12]
Local/regional recurrence (log_scale)	0.27	0.07	Weibull	[12]
Distant metastasis (base)	1.66	0.13	Exponential	[12]
Distant metastasis (tumor_site_specific)	-0.86	0.17	Exponential	[12]
Distant metastasis (log_scale)	0	0	Exponential	[12]
Oropharynx, stage I–II				
Mortality (base)	2.6	0.04	Weibull	[12]
Mortality (tumor_site_specific)	-0.19	0.18	Weibull	[12]
Mortality (log_scale)	-0.09	0.03	Weibull	[12]
Local/regional recurrence (base)	2.45	0.05	Weibull	[12]
Local/regional recurrence (tumor_site_specific)	0.11	0.23	Weibull	[12]
Local/regional recurrence (log_scale)	0.19	0.03	Weibull	[12]
Distant metastasis (base)	2.6	0.04	Weibull	[12]
Distant metastasis (tumor_site_specific)	-0.19	0.18	Weibull	[12]
Distant metastasis (log_scale)	-0.09	0.03	Weibull	[12]
Oropharynx, stage III–IV				
Mortality (base)	2.02	0.07	Weibull	[12]
Mortality (tumor_site_specific)	0.01	0.11	Weibull	[12]
Mortality (log_scale)	0.19	0.04	Weibull	[12]
Local/regional recurrence (base)	1.9	0.07	Weibull	[12]
Local/regional recurrence (tumor_site_specific)	0.13	0.13	Weibull	[12]
Local/regional recurrence (log_scale)	0.29	0.04	Weibull	[12]
Distant metastasis (base)	2.02	0.07	Weibull	[12]
Distant metastasis (tumor_site_specific)	0.01	0.11	Weibull	[12]
Distant metastasis (log_scale)	0.19	0.04	Weibull	[12]
Hazard ratios				
Hypopharynx vs. oropharynx	0.86	0.85–0.87	Lognormal	[13]
Oral cavity vs. oropharynx	1.06	1.09–1.03	Lognormal	[13]
Relative risks: new workflow vs. regular workflow				
Relative risk for local/regional recurrences when gained 1 mo in treatment delay	0.91	0.78–0.98	Lognormal	[4]

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Table 2 – *continued*

Parameter	Estimated value	SE/95% CI	Distribution	Source
Relative risk for distant metastases when gained 1 mo in treatment delay	0.66	0.26–1.06	Lognormal	[4]
Relative risk for death when gained 1 mo in treatment delay	0.9	0.76–0.98	Lognormal	[4]

CI, confidence interval; SE, standard error.
Gained waiting time is included as a parameter in the model on the basis of a beta PERT distribution and presented in more detail in Table 1.
* Interpretation parameters parametric survival model: $S(t)$ = survival probability at time $t = e^{-\lambda t\alpha}$. λ = event rate parameter = (base) + (tumor_site_specific). α = shape parameter indicating the time-dependent deviation = 1/(log_scale).

additional biopsy under full anesthesia had to be performed. They also included the costs for patients who received a diagnostic PET-CT in radiation therapy position with mask, but in the end appeared to have no indication for radiotherapy. Only the costs for the health care activities were included in this study.

To account for inflation rates, future QALYs and costs were discounted at 1.5% and 4%, respectively [17].

Markov Model Analysis

The life-years, QALYs, and expected total costs were calculated per tumor site and stage (eight patient groups) for the RWF as well as the NWF. The incremental cost-effectiveness ratio (ICER) was calculated by dividing the incremental (NWF minus RWF) costs by the incremental QALYs. This ICER represented the additional costs of one QALY when the NWF was implemented for the specific tumor site. A treatment is considered cost-effective when the ICER is below the price a patient (or the society) is willing to pay for an additional QALY (ceiling ratio). A ceiling ratio of €80,000 was adopted because this is the informal ceiling ratio for high-burden diseases in The Netherlands [18]. This means that society is willing to pay €80,000 for an additional year in perfect health. This ceiling ratio is relatively high compared with those used in other countries, for example, £20,000 to £50,000 in the United Kingdom [19]. Therefore, a more conservative ceiling ratio of €20,000 (used for non-destructive diseases in The Netherlands) was also considered [18].

Sensitivity Analysis

Probabilistic sensitivity analysis using Monte-Carlo simulation was performed to account for the uncertainty of the input parameters in the model [3]. The simulation incorporated 5000 iterations. The results of these simulations were illustrated using cost-effectiveness acceptability curves.

Extrapolation of Results

Patient outcomes were extrapolated to organizational and national levels (The Netherlands). The incremental net monetary benefit (INMB) was multiplied by the number of patients treated. The INMB is a representation of incremental gains/benefits (QALYs multiplied by the ceiling ratio) minus incremental costs [20]. For example, an INMB of €100 means that the total benefit of the proposed change exceeds the total costs with €100 on the long run. The INMB on the organizational level presented the number of patients treated within the studied organization (based on the annual reports of the two participating organizations) multiplied by the INMB. This organizational INMB represented the incremental benefit from the perspective of the health care payers and did not represent the incremental benefit or cost for the specific organization. The INMB extrapolated to the national level for The Netherlands was calculated by multiplying the incidence numbers from the Integral Cancer Centre for the four included treatment sites [21] and the INMB.

Results

Different gains in waiting time were realized for the eight included patient groups (Table 1). Gains in waiting times varied from 5 days gained for patients treated for oropharynx and hypopharynx tumors to 22 days gained for patients treated for larynx tumors. These gains in waiting time resulted in additional incremental QALYs varying from 0.13 for patients treated for hypopharynx tumors to 0.66 for patients treated for stage I and II larynx tumors (Table 3). The new care process (NWF) cost for patients with tumors located at the larynx and the oral cavity was less expensive than the RWF cost, which resulted in negative incremental costs. The 95% confidence interval for incremental costs showed a cost reduction ranging from €242 to €941 per patient treated for a larynx tumor and from €187 to €1437 per patient treated for a oral cavity tumor. Incremental costs for the NWF regarding oropharynx and hypopharynx tumors were small, varying from a mean additional cost of €304 to €453 per patient. As a result, ICERs presented a cost of approximately €2875 to €3777 for an additional QALY gained for patients with oropharynx tumors and €2119 to €2909 for patients with hypopharynx tumors (Table 3, and visualized in Figs. 2 and 3). The NWF was cost-effective for all studied treatment sites, using either the Dutch informal ceiling ratio of €80,000 for high-burden diseases or the more conservative ceiling ratio of €20,000. When using a ceiling ratio of €80,000, the summation of the individual INMB per treatment site and stage multiplied by the number of potential patients in the studied organization (Table 3) resulted in an organizational INMB of €14.1 million for the health care payer if the studied organization would implement the process redesign for all the patients treated for the included cancer sites. If the more conservative ceiling ratio of €20,000 was used, an organizational INMB of €3.6 million was calculated. Extrapolation to the national level of The Netherlands, using the Dutch ceiling ratio of €80,000 for high-burden diseases resulted in a national INMB of €91.5 million for the health care payer. If the more conservative ceiling ratio of €20,000 was used, a national INMB of €23.3 million was calculated.

Discussion

The NWF was cost-effective for all included patients with HNC. The NWF dominated the RWF for patients treated for cancer of the larynx and the oral cavity because of less costs and gained QALYs. The NWF for patients with hypopharynx and oropharynx cancers was also cost-effective for both ceiling ratios (€80,000 and €20,000). When society was willing to pay €2500 for a gained QALY for patients with hypopharynx cancer, and €3500 for patients with oropharynx cancer, the NWF was cost-effective. When INMBs were extrapolated to organizational and national levels, the

Table 3 – Outcomes of Markov model for the new workflow versus the regular workflow per treatment site and stage.

Outcomes		Larynx		Oropharynx		Hypopharynx		Oral cavity	
		I–II	III–IV	I–II	III–IV	I–II	III–IV	I–II	III–IV
Costs NWF	Mean	7806	15,739	13,588	16,015	13,377	15,700	5045	20,652
	95% CI	7260–8345	15,368–16,531	12,608–15,644	15,686–16,586	12,258–15,822	15,330–16,485	3512–11,542	19,904–21,634
Costs RWF	Mean	8445	15,993	13,135	15,562	13,068	15,397	5742	20,846
	95% CI	7883–8963	15,664–16,672	12,154–15,227	15,254–16,135	11,938–15,532	15,035–16,216	4070–8438	20,107–21,749
QALYs NWF	Mean	9.89	7.01	7.66	5.94	6.92	5.21	9.00	7.09
	95% CI	8.93–10.90	6.14–7.99	5.78–9.74	5.13–6.79	4.23–10.26	3.08–7.98	5.69–12.91	4.45–10.18
QALYs RWF	Mean	9.22	6.37	7.51	5.80	6.79	5.07	8.45	6.55
	95% CI	8.47–9.96	5.71–7.03	5.67–9.57	5.01–6.61	4.14–10.01	2.99–7.81	5.32–12.24	4.06–9.55
Incremental QALYs	Mean	0.66	0.65	0.15	0.15	0.13	0.13	0.55	0.54
	95% CI	0.10–1.32	0.09–1.31	0.02–0.31	0.03–0.31	0.02–0.30	0.03–0.29	0.09–1.19	0.10–1.16
Incremental costs	Mean	639	254	452	453	309	304	697	194
	95% CI	941 to 242	768 to 353	165–748	193–745	11–616	36–591	1.437 to 187	666 to 330
ICER	€/QALY	Dominant	Dominant	3090	3064	2300	2267	Dominant	Dominant
INMB calculated for a ceiling ratio of €80,000									
INMB per patient	Mean	53,703	51,916	11,260	11,380	10,430	10,408	44,309	43,782
	95% CI	9024–106,627	7994–105,569	1506–2463	1829–24,240	1500–23,359	1660–22,906	7690–95,812	7767–92,909
No. of patients in the organization*		89	89	46	46	22	22	36	36
Organizational INMB		4,779,543	4,620,529	517,973	523,471	229,452	228,973	1,595,137	1,576,153
No. of patients in The Netherlands†		355	355	227	227	113	113	528	528
National INMB		19,064,565	18,430,180	2,556,020	2,583,260	1,178,590	1,176,104	23,395,152	23,116,896
INMB calculated for a ceiling ratio of €20,000									
INMB per patient	Mean	13,905	13,170	2476	2505	2376	2374	11,600	11,091
	95% CI	2801–27,200	2196–26,498	34–5838	88–5741	117–5696	165–5530	2485–24,377	2026–23,432
Organizational INMB		1,237,545	1,172,130	113,896	115,230	52,272	52,228	417,600	399,276
National INMB		4,936,275	4,675,350	562,052	568,635	268,488	268,262	6,124,800	5,856,048

CI, confidence interval; ICER, incremental cost-effectiveness ratio; INMB, incremental net monetary benefit; NWF, new workflow; QALY, quality-adjusted life-year; RWF, regular workflow.

* The total number of patients per treatment site based on the organizational annual report of 2012. The total equally divided between stages I and II and III and IV.

† Numbers based on incidence numbers of Integral Cancer Centre in The Netherlands in 2012: www.cijfersoverkanker.nl.

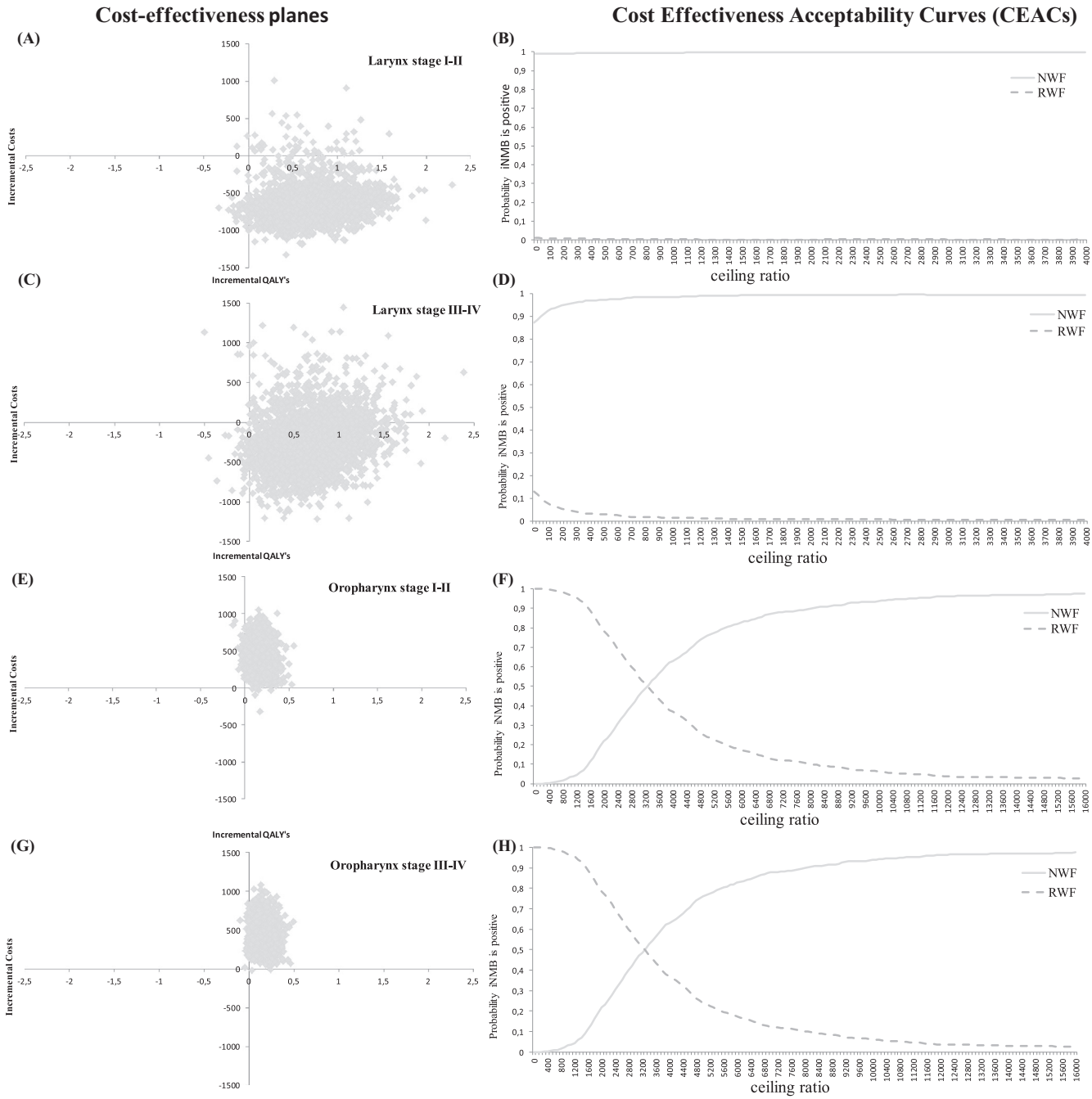

Fig. 2 – (A-H) Cost-effectiveness planes and cost-effectiveness acceptability curves (CEACs) of the redesigns for the treatment of tumors of the larynx and the oropharynx separated per stages. NWF, new workflow; QALYs, quality-adjusted life-years; RWF, regular workflow.

benefits of redesigning the workflow became very clear. When the Dutch ceiling ratio of €80,000 for high-burden diseases was used, an INMB of €14.1 million for the health care payers was calculated if the redesign would be fully implemented in the studied organization, and an INMB of €91.5 million if extrapolated to the national level. Even when the more conservative ceiling ratio of €20,000 was used, benefits remained obvious. This extrapolation of results, however, is purely indicative. The hypothetical extrapolation to the national level is based on the assumption that the redesign of the relevant processes would be comparable for all care organizations in The Netherlands. However, the reality is different. Furthermore, the incidence numbers of the tumor sites, which were used in the model to extrapolate results, were evenly distributed between stages I and II and stages III and IV, because the precise distribution between stages was not available. Therefore, this hypothetical extrapolation of the INMB serves only as an illustration of the potential benefits of relatively small logistical process improvements.

Differences in cost-effectiveness between tumor sites were partly based on differences in implementation costs between the two organizational changes. The biopsy under local anesthesia

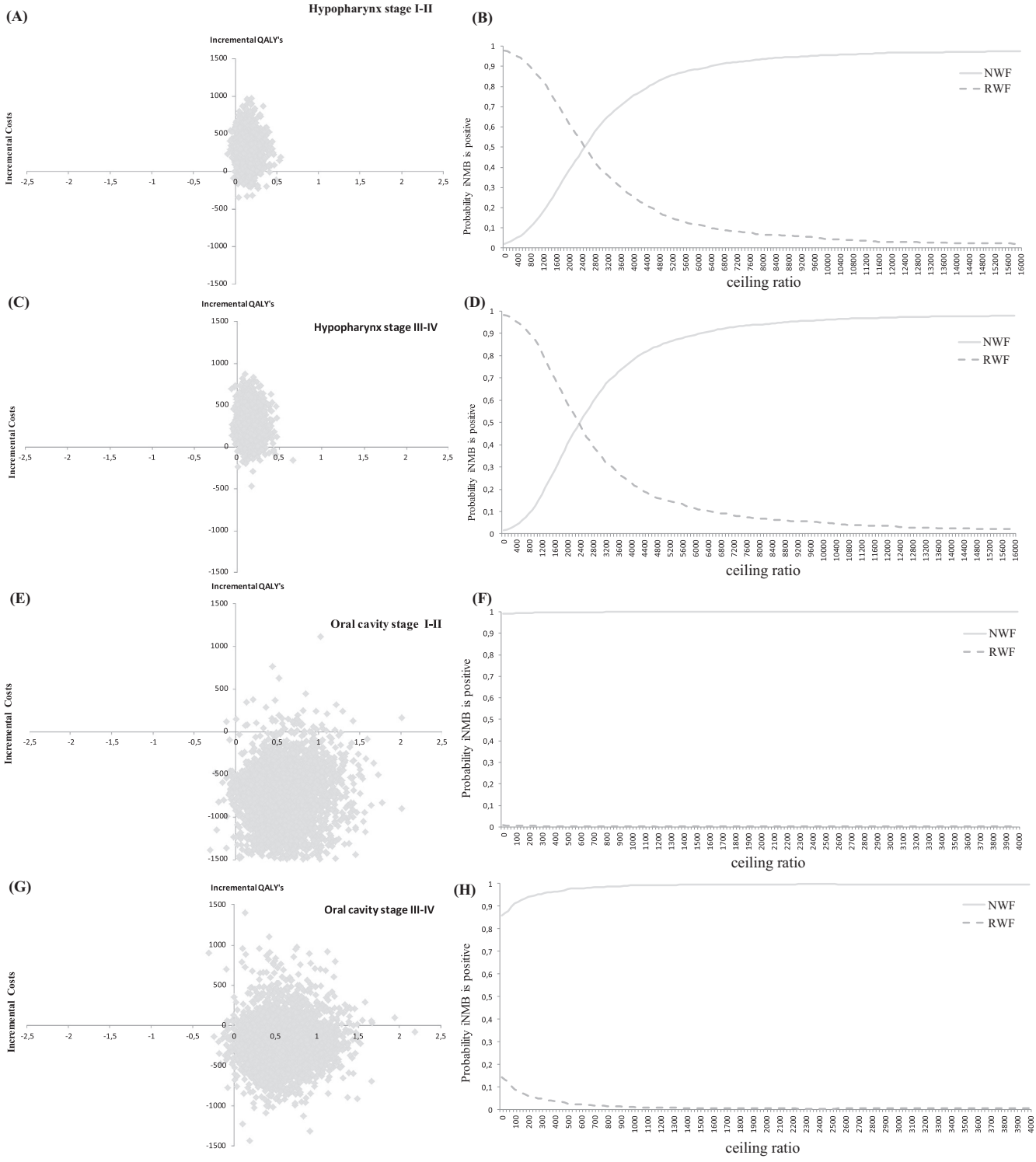

Fig. 3 – (A-H) Cost-effectiveness planes and cost-effectiveness acceptability curves (CEACs) of the redesigns for the treatment of tumors of the hypopharynx and the oral cavity separated per stages. NWF, new workflow; QALYs, quality-adjusted life-years; RWF, regular workflow.

(NWF) was less expensive than the regular biopsy under full anesthesia (RWF), whereas the NWF regarding the CT-PET process was more expensive than for the RWF. In addition, the redesigned biopsy process resulted in larger effects on gained waiting time whereas the redesign of the CT-PET process resulted in a larger number of gained QALYs. Because the cost-effectiveness acceptability curves presented the NWF for all patient groups as cost-effective at very small ceiling ratios, no additional one-way

sensitivity analysis was performed to calculate separate contributions of these uncertain parameters on the outcome.

Some limitations of this study should be discussed. First, the RRs for decreased waiting times were assumed equal for all eight sites and stages although these resulted in different transition probabilities between health states. Nevertheless, the effect of a decreased time to initiation of treatment could be considered more pronounced for faster growing tumors within patients with HNC. Second, one could question the assumption that the RR for decreased waiting time is linearly related to time, which directly affects the outcomes in the model. Third, the RRs used to configure the health states transition probabilities of patients with oropharynx tumors to those with hypopharynx and oral cavity tumors were assumed equal for survival, local/regional control, and metastases. This assumption, which could affect the outcomes, might be inconsistent with reality. Fourth, differences in QALYs between the NWF and the RWF might be underestimated because shortened time to treatment might result in smaller radiation treatment fields and, therefore, less radiation-related toxicity (improved quality of life for the NWF). Fifth, time gains from the introduced workflow were based on preliminary results from a pilot study. These might not represent the time gains that are aimed for because the organizations are still in a learning process, and might further improve the process to gain additional time. If waiting time is expected to further improve, the cost-effectiveness of the NWF is likely to improve as well. Sixth, the decreased time before patients were diagnosed could result in reduced stress levels for patients because living in uncertainty is extremely stressful, especially when cancer related. The potentially reduced stress level for the NWF was not included in the outcomes of the model. Seventh, a health care perspective was used for this model. All societal costs and benefits regarding the loss of productivity at work were not included. Incorporating these costs might improve the cost-effectiveness of the NWF because QALYs were gained, which could result in reduced loss of productivity. Eighth, because the model was based on the current existing literature, pilot data, and expert opinions, results should be carefully interpreted, and best be confirmed by results from a prospective study. Therefore, the presented results are mainly indicative regarding the possible benefits of efforts to redesign the care process.

Positive effects of the redesigned processes have to be mentioned as well. Patient groups, which were not incorporated in the outcomes of the model, benefited from the redesign as well. Because the biopsies of a number of patients were performed under local anesthesia, the operating room became available for other patients with HNC. Patients with locally advanced tumors, who were not included in the trajectory for biopsy under local anesthesia or who were on the waiting list for surgery, experienced less waiting time before treatment. Another positive effect of the study was a possibly improved diagnosis and treatment decision because PET-CT images became available during the diagnostic process instead of afterwards, and in particular before the performed biopsy.

Although health care professionals might be less attracted to process and organizational redesign than to adapting new technologies, the present study demonstrated that the redesign of a care process resulted in significantly better long-term patient outcomes and cost savings for particular patient groups. The reduction in waiting time for treatment is shown to positively affect patient prognosis [4,6,8]. An additional problem with process redesign interventions and a more efficient use of medical technologies is the inappropriate use of financial motivators. More efficient use of technologies, and redesigned care processes, which may result in benefits for the patient, might not be rewarded by finances or even result in fewer payments. This is an important impediment for creating efficient and high-quality care. To support efficient and qualitative care, organizations should be rewarded appropriately by the financers of care. This study proved that the reorganization of care processes can improve the efficiency of care, and reduce waiting times, resulting in improved patient outcomes. Therefore, interventions that aim to improve care by redesigning logistics deserve attention. The implementation of these redesign interventions on a much wider scale should be considered.

In conclusion, a redesign intervention of the diagnostic process and the radiotherapy preparation for patients with HNC resulted in reduced waiting time for treatment and more QALYs and proved to be cost-effective.

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Supplemental Material

Supplemental material accompanying this article can be found in the online version as a hyperlink at http://dx.doi.org/10.1016/j.jval.2015.04.003 or, if a hard copy of article, at www.valueinhealthjournal.com/issues (select volume, issue, and article).

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