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DR. FALK SCHWENDICKE (Orcid ID : 0000-0003-1223-1669)

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Professional oral healthcare for preventing nursing home-acquired pneumonia: a cost-effectiveness and value of information analysis

Falk Schwendicke[1], Michael Stolpe[2], Frauke Müller[3]

[1] Department of Operative and Preventive Dentistry, Charité – Universitätsmedizin Berlin, Germany

[2] Kiel Institute for the World Economy, Kiel, Germany

[3] Division of Gerodontology and Removable Prosthodontics, University Clinics of Dental Medicine, Geneva, Switzerland

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Corresponding author: Dr. Falk Schwendicke
Department of Operative and Preventive Dentistry
Charité – Universitätsmedizin Berlin
Aßmannshauser Str. 4-6
14197 Berlin
Tel.: (+49) 30 450 562 556
Fax: (+49) 30 450 562 932
Email: falk.schwendicke@charite.de

Aim: Professional oral healthcare (POHC) prevents nursing-home-acquired pneumonia (NHAP) and its related mortality. We assessed the cost-effectiveness of POHC versus no POHC (nPOHC) and the monetary value of eliminating uncertainty by future research.

Methods: A German public-private-payer-perspective was adopted. A Markov-model was used, following Long-Term-Care residents from admission to death. Cost-effectiveness was estimated as Euro/disability-adjusted-life-year (DALY) using Monte-Carlo microsimulations. Value-of-information analyses were performed. The willingness-to-pay-threshold/DALY was assumed to be 66% (range: 50-100%) of per-capita gross-domestic-product (GDP).

Results: nPOHC was less costly (3024 Euro) but also less effective (0.89 DALYs) than POHC (10249 Euro, 0.55 DALYs). For all presumed payers, POHC was cost-effective. The cost-effectiveness of POHC was higher in smokers, underweight or pulmonary disease patients. Eliminating uncertainty about the NHAP costs, NHAP incidence/mortality, and POHC effectiveness would result in an expected net value of 47 million Euro/year (and even higher values at lower GDP thresholds), and likely to decrease with time.

Conclusions: Within the chosen setting and on the basis of current evidence, POHC was cost-effective. Given the detected uncertainty, further research seems warranted.

Clinical Relevance

Scientific rationale: Professional oral healthcare (POHC) could prevent nursing-home-acquired pneumonia (NHAP), but generates substantial costs. These might be outweighed by savings for NHAP treatment. We assessed the cost-effectiveness of POHC.

Principal findings: POHC was costlier than not providing POHC. However, for all presumed German payers, POHC had acceptable cost-effectiveness. The cost-effectiveness is even higher in high-risk individuals or if POHC costs were lowered.

Practical implication: Delivering POHC will save lives and reduce NHAP-associated morbidity. The additional costs are likely to be acceptable for many payers. Targeting high-risk residents or lowering POHC costs will improve cost-effectiveness.

Introduction

Nursing-home acquired pneumonia (NHAP) is the major reason for hospitalization of Long-Term-Care (LTC) residents, presenting a mortality of up to 50% and generating significant healthcare costs (Welte et al., 2012). NHAP leads to substantial suffering from high fever, abundant bronchial secretions, dyspnoea, and feelings of suffocation (Janssens and Krause, 2004). NHAP is oftentimes caused by foreign material descending to the lung, most commonly saliva, biofilm or food debris (Müller, 2015). Oral bacterial species were identified in samples of broncho-alveolar lavages from pneumonia patients (Imsand et al., 2002). Poor oral hygiene and swallowing disorders were identified as most common risk factors for NHAP (Quagliarello et al., 2005). Patients with 10 or more natural teeth and periodontal pocket depth over 4 mm are at higher risk for NHAP (Awano et al., 2008).

Oral hygiene significantly reduces the risk of NHAP (Yoneyama et al., 2002, Ewig et al., 2012, Furman et al., 2004, Kaneoka et al., 2015, Muder, 1998, Sjögren et al., 2016). Two recent meta-analyses confirmed a reduced NHAP incidence and mortality in LTC residents, if regular professional oral healthcare (POHC), including removal of biofilm and calculus from teeth, mucosa and dental prostheses, was regularly provided by health professionals such as dental hygienists or dentists (Sjögren et al., 2016, Kaneoka et al., 2015).

However, POHC generates substantial costs for the intervention, the displacement of the health care professionals and the associated logistics (Bots-VantSpijker et al., 2014). Considering the limited funds in public health care systems, it is relevant to evaluate if POHC expenses are partially or fully offset by savings for reduced NHAP care. Moreover, it would be of scientific interest to know if future research on the effects of POHC on NHAP is likely to improve decision making, leading to reduced costs and improved health outcomes. Health economic analyses can be used to evaluate the monetary value of future research, and to assess how large a trial needed to be from a health economic perspective to close the present knowledge gaps. We aimed to assess the cost-effectiveness of POHC for reducing the incidence of NHAP and the monetary value of future research in this direction.

Methods

We performed (1) a cost-effectiveness analysis estimating the costs and health benefits of POHC with regards to NHAP, and (2) a value of information analyses quantifying the uncertainty about the true values of our cost-effectiveness estimates and the expected monetary benefit of further research to reduce this uncertainty.

Setting, perspective, population, horizon

This study adopted a mixed public-private-payer perspective in the context of the German healthcare system. A Markov decision model was constructed to follow residents in monthly cycles (TreeAge Pro 2013, TreeAge Software, Williamstown, MA, USA). We modelled a population of initially 77.5-years old individuals being admitted to LTC facilities, assuming their remaining lifetime (and thus the mean stay in the LTC) to be 30 months (range 1-120) (Kelly et al., 2010, deStatis, 2014). The overall population of LTC residents reported in 2015 for Germany was 783.000 (deStatis, 2015), with an estimated 313.000 persons being newly admitted every year.

Comparators and effectiveness data

We compared POHC for NHAP prevention versus no POHC (nPOHC). POHC was assumed to consist of weekly professional oral hygiene delivered by a dental hygienist or dentist including biofilm and calculus removal via scaling, tooth and mucosa brushing as well as denture cleaning (Adachi et al., 2002, Yoneyama et al., 2002, Kaneoka et al., 2015, Sjögren et al., 2016). Additional regular tooth brushing performed by nurses, family members or the resident him- or herself as well as the use of antibacterial rinses was assumed, but not accounted as POHC.

Based on synthesized international data, the median annual incidence of NHAP was estimated as 365 cases (range 92-912) per 1000 LTC residents (Muder, 1998). Based on a multi-centre prospective study in Germany, we assumed 44% of NHAP to be fatal within the first 180 days after diagnosis (Ewig et al., 2012). Treatment of NHAP included hospitalization and administration of antibiotics, with an average stay of 11 days in hospital (Ewig et al., 2012). Costs for NHAP treatment included diagnostics, hospitalization, medications, and further inpatient procedures. We did not further specify the treatment applied. Average costs and efficacies of treatments from a trial comparing different antibiotic regimen for community-acquired pneumonia were used (Lloyd et al., 2008).

Model and assumptions

A Markov model (Fig. 1) was constructed to follow patients over the following health states: (1) no NHAP, (2) non-fatal NHAP and treatment, (3) fatal NHAP and death. LTC residents were assumed to be at-risk for NHAP according to the documented incidence. Cases of NHAP could either show remission (non-fatal NHAP) or die from the disease (fatal NHAP).

Patients who recovered from NHAP were assumed to be at the same risk as before the incident. Note that this is likely to introduce some bias, as once affected by NHAP, patients might be at higher risk for re-infection. Model validation was performed internally by varying key parameters and by performing a range of sensitivity analyses.

Health outcome

Our health outcome was disability-adjusted life years (DALY), being the result of the period suffering from non-fatal NHAP (years lived with disease) or dying from it (years of life lost). A weighting factor was applied to estimate DALYs, ranging from zero (healthy) to one (dead). This disability weighting factor was multiplied with the time span of suffering. The disability weight for severe pneumonia was extracted from the Global Burden of Disease (GBD) study, under the assumption that in LTC residents all NHAP cases were severe (Salomon et al., 2010). It seems safe to assume, that for most residents in LTCs, the quality of life is somewhat reduced by functional impairment and chronic disease. We thus modelled such a background condition, using mild dementia in the base-case and moderate dementia in a sensitivity analysis.

Resources and costs

Cost calculations were based on the German statutory dental tariff, BEMA, and the private tariff, GOZ (KZBV, 2013). Fee items allow estimating costs occurring for a given treatment (Schwendicke et al., 2013). The majority of the German population (87%) are covered by the mandatory statutory medical insurance, which includes also dental treatments (GKV-Spitzenverband, 2013). Hence most fee items in our model were drawn from the statutory dental tariff. Only dental treatments which are not covered by the statutory insurance were taken from the private tariff GOZ, representing out-of-pocket expenses. In our model, the statutory tariff was used to calculate the costs of the dental health professional's displacement to the LTC facility, while the private tariff was employed to estimate costs of the professional biofilm and calculus removal. For the private tariff, factoring is common to reflect the efforts for different procedures in different patients. We used the standard GOZ factor, which is x 2.3.

Costs for treatment of pneumonia were estimated according to a large-scale German clinical trial comparing two different antibiotic regimens (Lloyd et al., 2008). As the trial reported both antibiotic regimen yielding very similar costs per case of NHAP from a payer's perspective, we considered this cost estimation to be robust. We assumed costs for managing fatal and non-fatal NHAP to be identical (this might not always hold true, with higher efforts possibly being needed to manage fatal NHAP).

Currency, price data, discounting

Costs were estimated in 2016 Euro. Costs reported in other years were adjusted according to the Harmonized Consumer Price Index (Statistisches Bundesamt, 2016). Future costs and effectiveness were discounted at 3% per annum (IQWiG, 2009). Discounting accounts for time preference, i.e. opportunities lost or gained by spending money now instead of later or experiencing health now instead of later. To explore the impact of higher or lower discounting, discount rates were varied between 0 and 5%.

Cost-effectiveness analyses

Monte-Carlo microsimulations were performed for analysis with 1000 residents being followed over 30 months. Based on estimates for costs (c, Euro) and effectiveness (e, DALYs), incremental cost-effectiveness ratios (ICERs), expressing cost differences per effectiveness differences, were calculated.

To introduce parameter uncertainty, we performed a number of univariate sensitivity analyses, varying for example the costs for POHC and the incidence of NHAP in different risk groups. Additionally, parameters were randomly drawn from uncertainty distributions (Briggs et al., 2002). Such random samples were drawn 1000 times. The net monetary benefit (NMB) of each strategy combination was calculated using the formula NMB $= \lambda \times \Delta e - \Delta c$, with λ denoting the ceiling threshold of willingness-to-pay, i.e. the additional costs a decision maker is willing to bear for gaining an additional unit of effectiveness (Drummond et al., 2005). If $\lambda > \Delta c/\Delta e$, an alternative intervention is considered more cost-effective than the comparator, although it may be more expensive (Briggs et al., 2002). We used this approach to calculate the acceptability of POHC regarding its cost-effectiveness for payers with different willingness-to-pay ceilings.

For many countries a standard willingness-to-pay threshold has been defined or agreed on (World Health Organization, 2014), but not for Germany. We needed to rely on an arbitrary threshold, like a percentage of the gross domestic product (GDP) per capita (46154 Euro in 2016) (deStatis, 2017) or similar estimations (Woods et al., 2016, Robinson et al., 2016). The WHO, for example, recommends a 100% GDP threshold to be used. Others have comparatively assessed existing thresholds and have found that for a country like Germany, a realistic threshold would, depending on a number of assumptions and accounting for purchasing-power, range 48-85% of the GDP. To account for this range of possible thresholds, we used (a) a mean of this interval, i.e. 66% of GDP (30461 Euro), in our base-case analysis, (b) a minimum of 50% GDP (23077 Euro) and (c) a maximum of 100% GDP (46154 Euro) in two sensitivity analyses (Woods et al., 2016, Nimdet et al., 2015).

Value of information analyses

Cost-effectiveness analyses indicate which strategy is preferable at different willingness-to-pay thresholds, accepting a number of uncertainties around input parameters. Further research might reduce these uncertainties, which could lead to health gains or cost reductions from improved resource allocation. Value of information analyses can assist in assessing the foregone benefits and costs of imperfect information.

We describe the details of our value of information analyses in the appendix. Briefly, the average NMB at a chosen willingness-to-pay threshold (here: 66% GDP) was calculated, accounting for the uncertainty about the true values of various parameters. To estimate how perfect knowledge would change the NMB, one can now identify the strategy with the highest NMB at each simulation and compare the average NMB of these “ideal” strategies with the NMB under imperfect information (Claxton, 1999). The resulting expected value of perfect information (EVPI) was calculated per individual and on population level (Griffin et al., 2006). Moreover, the value of knowing specific parameters without uncertainty (the so called expected value of partial perfect information, EVPPI) was calculated (Ford et al., 2012). EVPPI is helpful to identify the most relevant parameters from a cost-effectiveness perspective, which might be prioritized in future research. We assessed the value of reducing the uncertainty about the true values of POHC costs and effectiveness, the disability weight for NHAP, its incidence/mortality and the costs for managing NHAP.

Lastly, the monetary value of conducting future research, in form of a two-arm randomized controlled trial was calculated. The resulting reduced value of uncertainty is called expected value of sampling information (EVSI) (Claxton and Posnett, 1996). This implies calculating how better knowledge from a future trial could reduce costs and hence change effectiveness. This value is then contrasted with the costs for a future trial. We varied possible trial sample sizes between 100 and 500 patients per study arm. The costs of trials with different sample sizes were then subtracted from the EVSI, yielding the expected net monetary benefit of sampling (ENBS) (Claxton and Posnett, 1996).

Results

Study parameters

Model estimates and resources can be found in Table 1, including distribution and sources.

Cost-effectiveness analysis

When using the most likely input parameters, called the “base-case scenario”, nPOHC was least costly (3024 Euro) but also least effective (0.89 DALYs). POHC was costlier (10249 Euro), but also more effective (0.55 DALYs, ICER 21230 Euro/averted DALY). Figure 2a depicts the incremental costs and effectiveness. In 87% of the simulations, POHC was the cost-effective choice when applying the willingness-to-pay threshold of 66%. Respective numbers for 50% and 100% GDP were 71% and 99%.

For payers not willing to invest additional money per health gain, nPOHC was most likely cost-effective. For payers willing to invest λ=21230 Euro per averted DALY, both strategies were similarly likely to be cost-effective. Above this λ, POHC was more likely to be cost-effective (Fig. 2b).

Sensitivity analyses

Table 2 depicts findings of the sensitivity analyses. Modelling moderate dementia as background condition significantly increased the ICER, as the advantage of living longer when provided with POHC came at significantly limited quality of life; the ICER was 32840 (i.e. the condition was not cost-effective under a 66%, but a 100% GDP willingness-to-pay threshold). The cost-effectiveness of POHC was improved in individuals with high risk for NHAP, such as smokers or those with chronic obstructive pulmonary disease (COPD). In such individuals, the ICER was below 15000 Euro/averted DALY, i.e. well below any assumed willingness-to-pay thresholds. The same applied if POHC costs were assumed to be at the lower estimated end of possible costs. Discounting had only very limited effect on ICER and is therefore not shown.

Value of information analyses

At the assumed base-case willingness-to-pay level of 66% of GDP (30461 Euro/DALY), there were a number of simulations where nPOHC would have been the better choice; saving money (but losing effectiveness). Eliminating this uncertainty led to an EVPI of 150 Euro (Fig. 2c). The total EVPI was near 47 million Euro per year in Germany. At thresholds of 50% and 100% GDP, the EVPI was 294 and 15 Euro per individual, respectively.

When evaluating the impact of specific parameter uncertainty (EVPPI) for payers with a willingness-to-pay of 66% GDP (Tab. 3), all parameters had only limited EVPPI (as POHC was nearly always cost-effective). For such payers, the costs of NHAP were the most relevant parameter, followed by information on NHAP incidence/mortality, the effectiveness of POHC, its costs and the disability weight assigned to NHAP.

When assessing how a future trial would reduce uncertainty and improve decision making, we found the highest expected net monetary benefit of sampling (ENBS) for an RCT with n=100 per arm. For larger numbers of study participants, the value of information gains did not outweigh the trial costs (Fig. 3).

Discussion

In recent decades, older individuals lose their teeth later in life, with the natural dentition requiring skilled and time-consuming oral hygiene measures, which often exceed the competence and available time of both patients and nursing staff (Peltola et al., 2004, Bots-

VantSpijker et al., 2014). The resulting poor oral hygiene is a risk factor for NHAP (Quagliarello et al., 2005). We found POHC to prevent NHAP and to be cost-effective, within German healthcare and assuming willingness-to-pay thresholds of 50% GDP or above. The cost-effectiveness decreased when assuming residents to have severe background conditions which significantly impair quality of life (like but not exclusively, moderate dementia), mainly as the extended lifetime came at decreased quality of life. Given our estimates, future trials on POHC for preventing NHAP might have moderate expected net benefit, requiring the recruitment of only moderate sample sizes.

The present study has a number of limitations. First, the estimated costs are only applicable for the German system, which limits extrapolation of the obtained results. Costs for managing NHAP were derived from a single (albeit large, multi-centre) study on community-acquired pneumonia; costs for managing NHAP are possibly higher, increasing the cost-effectiveness of POHC. Costs further apply only to the German population with compulsory insurance, not for privately insured patients. However, costs were reported to differ very little when estimated from private instead of statutory tariffs (Schwendicke et al., 2014, Schwendicke et al., 2016).

Secondly, our model takes only oral hygiene related preventive measures into account, but other interventions, like denture abstention during the night (Iinuma et al., 2015) or the intake of Vitamin D may also prevent pneumonia (Martineau et al., 2017). Adding these measures to a POHC intervention might generate only very limited costs, but have considerable effectiveness advantages. It is also unclear how this affects cost-effectiveness if these co-interventions would be provided to both the POHC and the nPOHC group.

Thirdly, data on the risk of NHAP in sensitivity/subgroup analyses came from partitioned analyses (comparing, for example, smokers versus non-smokers). However, we used them as if they came from an analysis comparing smokers versus all individuals (the same applies for other subgroup analyses). This approach was chosen as only these data were available.

However, it might lead to some over-estimation of relative risks (and thus over-estimation of the cost-effectiveness differences).

Lastly, we calculated the costs for POHC assuming it would be provided by a dentist or dental hygienist, hence POHC being relatively costly. It is conceivable, that the costs of POHC could be reduced, if it was regularly applied within a specifically priced context, or be group-ordered to reduce travel costs. Moreover, the interval of POHC might be changed (current studies only assessed weekly POHC); it should be noted that this could also impact on effectiveness. Lastly, delegating POHC to nurses or non-dental staff might reduce costs substantially (which could, as shown, increase cost-effectiveness), but they have to be trained accordingly to be effective. At any rate, the effectiveness of such delegated interventions has not been confirmed yet (Sjögren et al., 2008), mainly as the fidelity and maintenance of such intervention provided by nurses might be relatively low.

The calculated cost-effectiveness of POHC may be used to convince health policy makers to provide POHC to dependent elders. Cost-effectiveness would be particularly favourable in high risk patients (smokers, underweight patients, those with COPD or diabetes), but even without these particular risks, POHC was cost-effective. When modelling a significant background condition like moderate dementia, the relative advantage was decreased. It has also to be noted, that the acceptability varied largely depending on the willingness-to-pay: in our study, we chose a base-case threshold of 66% of per-capita GDP, which is rather conservative. Where higher thresholds are applied (USA, Canada or UK), POHC becomes even more cost-effective.

Future trials would yield relevant information. An EVPI of 150 Euro per patient was calculated, which seems modest in the context of the costs for treating NHAP (which can amount to 10000 Euro or more). However, assuming that 330000 elderly persons are admitted to a LTC facility every year, the population-level EVPI would be considerable. We found a trial involving 100 patients per arm to be cost-effective, with the expected trial costs being lower than the population level gains from better information. Given the high cost-effectiveness of POHC based on current information, however, the overall EVSI was limited. It should be noted that the value of information might be increased in case a trial would yield information on other parameters, which we have not accounted for, or include additional intervention (components) which might make the overall intervention more effective. On the other hand, we assumed the lifetime of the costs and benefits stemming from POHC would be permanent, while this is unlikely to be true: If a new technology (say, a cheap and effective drug against NHAP) would be introduced, the cost-effectiveness of POHC would decrease. This has implications for the EVPI and ENBS; both are thus likely to be lower than estimated.

A number of recommendations can be derived from our study. Nursing homes should seek to involve dental care professionals in regular POHC. The prevention of pneumonia is likely to save lives and reduce NHAP-associated morbidity. Further benefits from POHC may arise from better oral health impacting on cardiovascular diseases (Janket et al., 2003, Lafon et al., 2014) and diabetes (Hasuike et al., 2017), but also from reducing caries and periodontal disease, thereby preventing tooth loss. Last, but by far not least, psycho-social advantages from preventing bad breath and poor dental appearance are relevant, as less inhibited social interactions will enhance subjective well-being in many elderly adults.

From a research perspective, it can be recommended to prioritize future research on the true costs of NHAP and POHC, the incidence and mortality of NHAP and the effectiveness of POHC and other interventions on NHAP. For POHC, a trial involving 100 individuals per arm can be recommended. Additional research might be needed to evaluate how the translation of clinical research into daily care can best be achieved (i.e. how fidelity and reach of the intervention can be optimized). Moreover, the delegation of POHC to nurses should be researched in more detail, as this might come with relevant cost-effectiveness advantages.

Conclusion

Within the German healthcare setting and on the basis of current evidence, POHC generates substantial costs (at least when provided by dental staff in high frequency), but reduces mortality and morbidity from NHAP. We found POHC to be cost-effective for payers with a willingness-to-pay threshold exceeding 50% GDP. Future research should evaluate how POHC can be delivered with similar effectiveness at lower costs, and should aim to close knowledge gaps around the real costs and effectiveness of POHC.

List of abbreviations

NHAP	Nursing-home acquired pneumonia
LTC	Long-Term-Care
POHC	Professional oral health care
nPOHC	no Professional oral health care
DALY	disability-adjusted life years
GBD	Global Burden of Disease
BEMA	Bewertungsmaßstab
GOZ	Gebührenordnung für Zahnärzte
c	costs
e	effectiveness
ICER	incremental cost-effectiveness ratios
NMB	net monetary benefit
GDP	gross domestic product
EVSI	expected value of sampling information
EVPI	expected value of perfect information
EVPPI	value of partial perfect information
ENBS	expected net monetary benefit of sampling
COPD	chronic obstructive pulmonary disease
ENBS	expected net monetary benefit of sampling

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Figure legends

Figure 1: Markov model structure. Healthy patients could (a) remain healthy, (b) experience NHAP and be successfully treated and recover, or (c) die from it. POHC: professional oral healthcare. NHAP nursing-home acquired pneumonia. Only the arm for POHC is shown.

Figure 2: Incremental cost-effectiveness plane, net-benefit analysis and expected value of perfect information (EVPI) curve in the base-case analysis. (a) The incremental costs and effectiveness of POHC versus nPOHC were plotted. The dotted line indicates the willingness-to-pay threshold of 66% per-capita GDP. (b) Cost-effectiveness acceptability curve. The cost-acceptability was plotted depending on the willingness-to-pay threshold of a payer. By increasing the willingness-to-pay, POHC becomes more acceptable. (c) The EVPI is 0 at low willingness-to-pay threshold values: For such payers, nPOHC is always the best choice. It is also 0 for payers with relatively high threshold values: For these payers, POHC

is always the best choice. EVPI is highest at a willingness-to-pay value of 21230 Euro. For payers with a willingness-to-pay threshold of 66% per-capita GDP, EVPI was 150 Euro.

Figure 3: Expected value of sampling information (EVSI, on population level), trial costs and expected net benefit of sampling (ENBS) at different sample sizes (n, per arm). As trial costs increase with increasing n, but additional EVSI is limited, the ENBS decreases from a certain sample size on (to negative values). We found the optimal sample size from a cost-effectiveness consideration to be at n=100/arm, while above n=150 (dotted line), costs would even outweigh benefits.

Tables

Table 1: Model estimates and sources. Various parameters came with mean (most probable) values, and uncertainty about their true values. This uncertainty was expressed by triangular distributions (which can be interpreted as minimum; mean; maximum multiplication factors, which are randomly drawn during the simulations). For POHC, costs for the visit and travel, possible additional costs for treating dependent patients, and costs for the oral health assessment and professional cleaning were considered. Costs were calculated for one session per week. The minimal costs included the visit including travel, clinical assessment and POHC costs, and were estimated at 48.06 Euro per patient. Costs may be higher, if, for example, the treatment of dependent patients was charged separately. By adding such costs, we reached maximum costs for 77.91 Euro.

Parameter	Value	Triang. dist.	Source
Pneumonia incidence/y	0.365	0.27;1.00;2.5	(Muder, 1998, Ewig et al., 2012)
Pneumonia mortality/y	0.161	0.27;1.00;2.5	(Ewig et al., 2012)
POHC: effect on non-fatal pneumonia	RR: 0.61	0.66;1.00;1.50	(Kaneoka et al., 2015)
POHC: effect on fatal pneumonia	RR: 0.41	0.55;1.00;1,73	
Disability-weight pneumonia	0.210	0.66;1.00;1.41	(Salomon et al., 2010)

Disability-weight mild dementia	0.069	0.67;1.00;1.33	
Disability-weight moderate dementia	0.377	0.67;1.00;1.33	
Risk adjustment NHAP incidence in			
smokers	2.01	0.63;1.00;1.68	(Loeb et al., 2009)
COPD	2.49	0.91;1.00;1.09	(Langmore et al., 2002)
underweight	1.83	0.65;1.00;1.53	(Loeb et al., 2009)
diabetes mellitus	1.26	0.96;1.00;1.04	(Kornum et al., 2008)

Cost items*	**Position**	**Euro***	**Source/comment**
Costs for POHC: Visit, first patient	BEMA 154	27.16	(KZBV, 2016, KZBV, 2013)
Visit, per further patient	BEMA 155	24.96	Visiting costs are charged per patient, and are higher for the first than for subsequent patients. Visiting cost include a fixed fee and a distance-charge (per km driven; charged once). Additionally, charges for treating dependent patients might apply.
Subtotal visit charge/patient		24.99	
Km charge, assuming 5-10 km	BEMA 7830	12.30	
Km charge per patient		0.20	
	BEMA 172a	34.62	
Add. for dependent patients, first patient			
Add. for dependent patients, further patients	BEMA 172b	29.77	
Subtotal add. costs		29.85	
Oral health assessment every 6 months	BEMA 172c	15.52	We assumed the oral health to be assessed every 6 months by a dentist. Costs were distributed per visit (assuming weekly visits).
Subtotal per visit		0.85	
Professional cleaning (6 teeth)*	GOZ 1040	22.02	Cleaning is charged per tooth. We assumed 6 teeth to be present (Jordan and Micheelis, 2016).
TOTAL per POHC (min-max)	-	48.06-77.91	
TOTAL pneumonia treatment (mean, 95% CI)	-	3066 (SD 1085)	(Lloyd et al., 2008)

*assuming cooperation contract between dental care professional and nursing home; assuming insured at largest insurer; assuming 63 patients per nursing home (https://www.destatis.de/DE/Publikationen/Thematisch/Gesundheit/Pflege/PflegeDeutschlandergebnisse5224001139004.pdf?__blob=publicationFile);

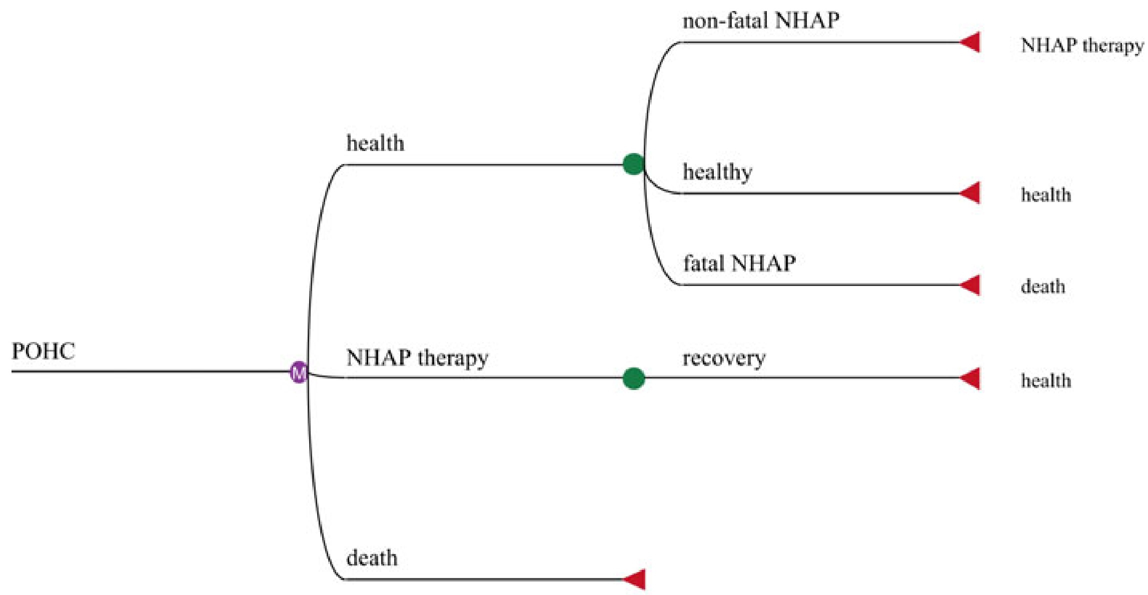
Table 2: Cost-effectiveness in the base-case and sensitivity analyses.

Scenario	**POHC**		**nPOHC**		
	c (Euro)	**e (DALYs)**	**c (Euro)**	**e (DALYs)**	**ICER (Euro/DALYs)**
Base-case	10249	0.55	3024	0.89	21230
Assuming generalized moderate dementia	10249	1.31	3024	1.53	32840
Smokers	10835	0.81	4714	1.29	12561
COPD	11729	0.85	5266	1.43	10490
Underweight	10769	0.76	4451	1.22	13816
Diabetes mellitus	10441	0.62	3546	1.01	17765
Costs POHC 41 Euro/ intervention	7388	0.55	3024	0.89	12835

Costs (c) and effectiveness (e) are displayed. The additional costs per gained effectiveness when choosing POHC instead of nPOHC is displayed, this ratio is called the incremental cost-effectiveness ratio (ICER).

Table 3: Expected value of perfect information. The value of having perfect information on all (EVPI) or a range of parameters (EVPPI) is given on patient and population level, with the population entering care homes in 2016 being the target population.

Parameter	**Euro / patient**	**Million Euro / target populat**
EVPI	150.00	46.95
EVPPI (ranked)		
Costs NHAP	8.10	2.53
Incidence/mortality data	6.11	1.91
Effectiveness POHC	5.50	1.73
Costs POHC	5.12	1.60
Disability weight NHAP	2.18	0.68


non-fatal NHAP
NHAP therapy
health
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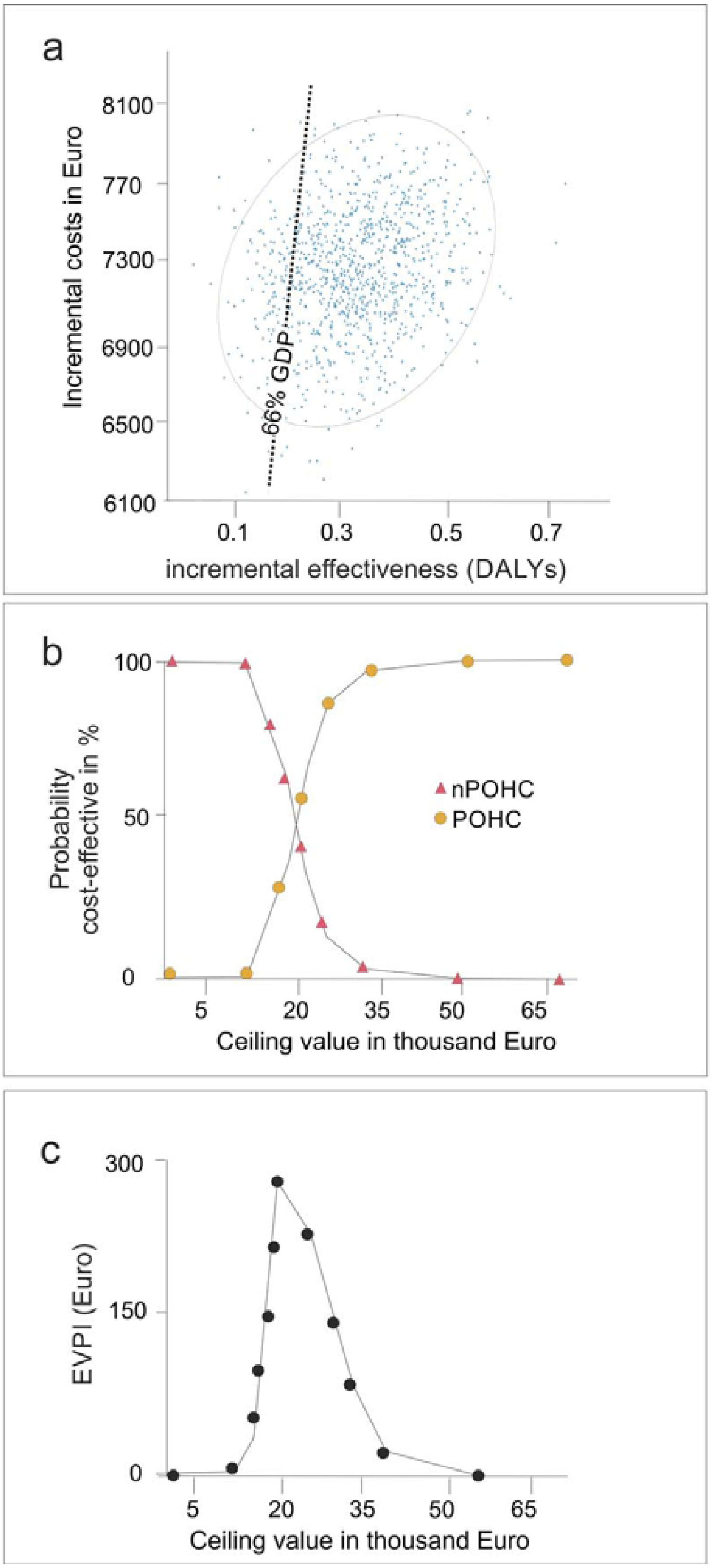
a
8100
770
7300
6900
6500
6100
Incremental costs in Euro
66% GDP
0.1
0.3
0.5
0.7
incremental effectiveness (DALYs)
b
100
50
0
Probability cost-effective in %
nPOHC
POHC
5
20
35
50
65
Ceiling value in thousand Euro
c
300
150
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EVPI (Euro)
5
20
35
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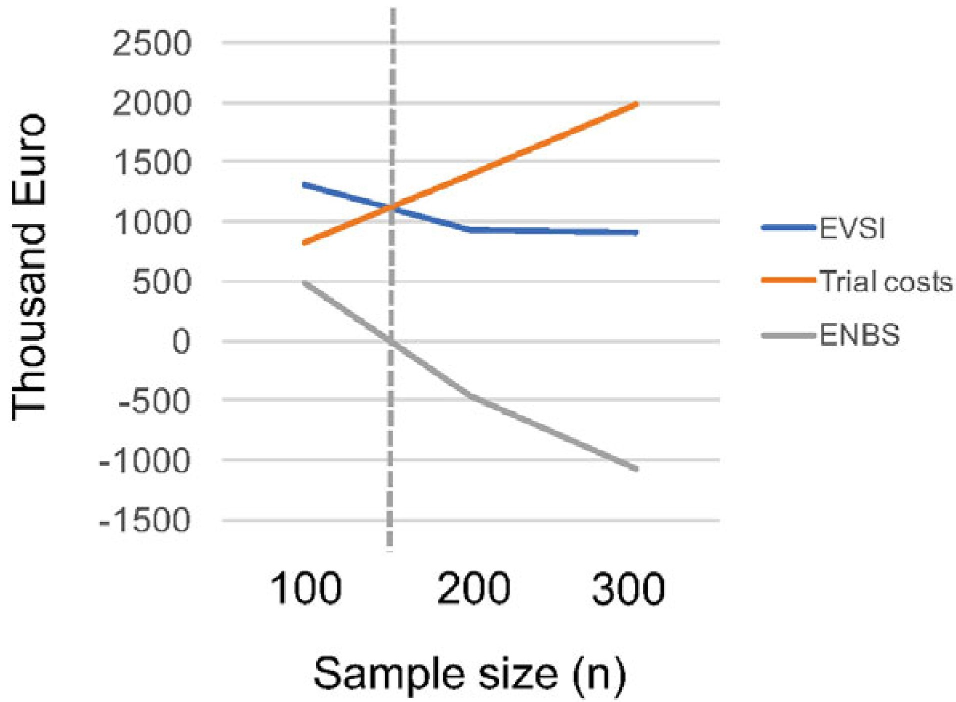
65
Ceiling value in thousand Euro



2500
2000
1500
1000
500
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-500
-1000
-1500
Thousand Euro
100
200
300
Sample size (n)
EVSI
Trial costs
ENBS