Decision-analytic modeling is increasingly advocated for use during the early development stages of new medical technologies, i.e. from initial ideas through Phase III-like trials anticipating market access and reimbursement [1-3]. The rationale behind early modeling is to inform internal investment decisions to prioritise potential products or prototypes to take forward, thus avoiding investments in product development that are less likely to be successful. In addition, during the development stage there is still scope for further research and development on product design before being brought to market. R&D resources could be directed more efficiently through formal analysis that is aimed at identifying users’ product attribute preferences and that elicits the expected technological performance of those attributes. Ultimately, this should lead to better designed products that are more rapidly available to patients.

Yet, decision-analysis in the very early stages of product development is challenged typically by a lack of data. Especially in the field of medical devices, these early stages are often termed as “evidence free zones.” In such a context, formal methods can be used to elicit expert knowledge on the parameters of interest to populate our decision models. One such method is the Analytic Hierarchy Process (AHP), a technique for multi-criteria decision analysis. We explored AHP to 1) support the estimation of model inputs for which no empirical data are available yet, and 2) offer a weighting procedure to combine multiple (additional) criteria in the estimation of decision-relevant utilities, which are experienced by technology users but may not be explicitly captured in regular utility measures.

As a first illustration of AHP, we introduce a previously published Markov model that predicts the outcomes of photo acoustic mammography (PAM) as a new second-line imaging technology after an initial ultrasound test was found positive to diagnose breast cancer [4]. To aid in internal investment decisions, this model compares the cost-effectiveness of PAM relative to current practice with magnet resonance imaging (MRI). In this illustration, we describe how AHP supported elicitation of expert knowledge to estimate PAM sensitivity, specificity, patient comfort and risks, and how the results were incorporated into the decision analysis to improve the validity of the Markov model.

The Analytic Hierarchy Process (AHP)
Techniques for multi-criteria decision analysis originate from operations research. They help decision-makers assess health care technologies under a finite number of criteria. Saaty’s AHP is a validated technique for multi-criteria decision analysis [5]. Dolan et al. [6], Hummel et al. [7], Hummel and IJzerman [8,9] showed that the AHP is valuable to support health care decision-making. Based on a pairwise comparison technique, the AHP quantitatively compares how important multiple criteria are in assessing health care technologies and how well these alternative technologies perform in fulfilling these criteria. An ordinal scale refines the pairwise comparisons between two criteria or two technologies. The psychometric scales range from the numerical value 1, reflecting equal importance or performance, up to and including 9, reflecting extremely greater importance or performance. An eigenvector approach is used to calculate weighting factors that reflect the importance of the criteria and priorities that reflect the performance of the alternative technologies. The weighted average of the performance scores on all criteria is the overall priority of a health care technology. In these paired comparisons, the responses reflect judgments of relative importance, not preferences revealed through binary choices, such as in discrete choice or ranking studies. Psychometric scales provide richer data than binaries (e.g., better for small samples), but require further assumptions for statistical aggregation, similar to the visual analogue scale (VAS) in the health valuation literature.

Using the AHP in Elicitation of Expert Knowledge
The AHP supported elicitation of knowledge of an expert panel that consisted of radiologists, oncologists, physicists, and a nurse practitioner. These experts first judged the importance of criteria related to the sensitivity, specificity, patient comfort, and safety in assessing breast cancer imaging techniques. Regarding the sensitivity and specificity, the experts estimated the importance of tissue-related and physiological characteristics in diagnosing breast tumors. For example, these characteristics included the shape of the tumor or the vascularization around the tumor. Furthermore, the experts compared the expected performance of PAM relative to the gold standard MRI on each of the identified characteristics. For instance, they compared which technology could identify the shape of the tumor better, and to what extent. The weighted average performance of the imaging techniques represented the expected relative sensitivity and specificity of PAM in comparison with MRI.

Likewise, the new PAM imaging technique was compared to the performance of MRI concerning patient comfort and safety. Criteria related to patient comfort were body contact, environmental impact, and time between scan and result.>
Criteria related to safety were physical exposure, chemical exposure, and bodily burden. Figure 1 shows the criteria used to compare the performance of PAM with MRI.

AHP-Derived Estimations

The panel, consisting of seven experts, estimated the sensitivity of breast cancer imaging techniques to be most important (weight = 0.55), followed by safety (weight = 0.26), specificity (weight = 0.14) and patient comfort (weight = 0.05).

The new technique is expected to have a minimally higher sensitivity than MRI has (priority PAM = 0.51; priority MRI = 0.49). In contrast, the specificity of PAM is expected to be slightly lower than MRI (priority PAM = 0.46; priority MRI = 0.54). PAM is expected to be less uncomfortable to patients (priority PAM = 0.61; priority MRI = 0.39) and to be safer than MRI (priority PAM = 0.77; priority MRI = 0.33). Regardless of its diagnostic performance, PAM offers additional advantages compared to MRI regarding these two criteria of patient comfort and safety.

Converting the AHP-Derived Estimations to Inputs in Markov Decision Models

By using an approximation of the priority value function of the AHP, we calibrated the relative priorities for the sensitivity and specificity into absolute values for the sensitivity and specificity of PAM on a health utility scale. We combined the relative priorities of PAM with the known absolute sensitivity and specificity of MRI (sensitivity PAM = 0.864; sensitivity MRI = 0.860; specificity PAM = 0.88; specificity MRI = 0.90). These estimations of the sensitivity and specificity of PAM were used as direct inputs in the Markov decision model.

Since patient comfort and safety were not explicit parameters in the Markov model, but were shown to be important based on the AHP results, we used the AHP-derived estimations of patient comfort and safety as indirect inputs in the Markov decision model. By knowing the impact of sensitivity on health utility from the Markov model and assuming that a criterion with a lower weight will have a lower impact on health utility, we estimated the impact of patient comfort and safety on health utility. Patient comfort can cause a temporary disutility in the period of the diagnostic test. Risks associated with the diagnostic test can cause temporary disutilities (e.g., allergic reaction) as well as long-term disutilities (e.g., cell damage). The assumption that the weight of the criterion is positively correlated to the impact on health utility was validated by one-way sensitivity analyses of sensitivity and specificity on generated utility using the Markov decision model.

Way Forward

The AHP can contribute to the systematic assessment of relatively new technology, where clinical evidence is not yet available or incomplete. Furthermore, we show that the AHP estimates may serve as a context-specific adjustment tool for general health utility measures, such as quality-adjusted life years. Accordingly, incorporating the AHP produced a more holistic impact of the new breast cancer imaging technique on decision-relevant health outcomes.

The AHP is appropriate to structure complex decisions. It decomposes the decision about the relative performance of a new technology compared to the gold standard in a series of pairwise comparisons with psychometric scales of relative importance. By comparing the performance regarding each determinant of sensitivity and specificity, a systematic approach is offered to estimate such complex parameters like the sensitivity and specificity of diagnostic devices.

In addition, the AHP allows the integration of context-specific effects of the imaging techniques in the decision model besides the diagnostic performance. These effects can cause additional and often temporary disutilities to the health states of patients. In this specific case, additional disutilities caused by patient comfort and safety only had a low impact on health outcomes. In other cases, however, one could image a stronger impact of factors such as patient discomfort. For example in the case of population screening, patient discomfort and risks associated with the health care intervention become relatively more important. Then the additional utility of PAM on these criteria may increase the future uptake of the new intervention in health care.

By eliciting importance estimates from a small panel of experts and incorporating these estimates in the Markov decision model, the AHP enhances the predictive validity of early decision-analytic models.

References