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Value Based Decision Support to Prioritize Development of Innovative Technologies for Image-Guided Vascular Surgery in the Hybrid Operating Theater

Friso G. Heslinga[a], Hendrik Koffijberg[a], Robert H. Geelkerken[b,c], Robbert Meerwaldt[c], Thijs G. ter Mors[d], Carine J.M. Doggen[a], and Marjan Hummel[a]

[a]Department of Health Technology & Services Research, Technical Medical Centre, University of Twente, Enschede, the Netherlands
[b]Department of Multi-Modality Medical Imaging, Technical Medical Centre, University of Twente, Enschede, the Netherlands
[c]Department of Vascular Surgery, Medical Spectrum Twente, Enschede, the Netherlands
[d]GE Healthcare, Hoevelaken, The Netherlands

ABSTRACT

Innovative technologies for minimally invasive interventions have the potential to add value to vascular procedures in the hybrid operating theater (HOT). Restricted budgets require prioritization of the development of these technologies. We aim to provide vascular surgeons with a structured methodology to incorporate possibly conflicting criteria in prioritizing the development of new technologies. We propose a multi-criteria decision analysis framework to evaluate the value of innovative technologies for the HOT based on the MACBETH methodology. The framework is applied to a specific case: the new HOT in a large teaching hospital. Three upcoming innovations are scored for three different endovascular procedures. Two vascular surgeons scored the expected performance of these innovations for each of the procedures on six performance criteria and weighed the importance of these criteria. The overall value of the innovations was calculated as the weighted average of the performance scores. On a scale from 0-100 describing the overall value, the current HOT scored halfway the scale (49.9). A wound perfusion measurement tool scored highest (69.1) of the three innovations, mainly due to the relatively high score for crural revascularization procedures (72). The novel framework could be used to determine the relative value of innovative technologies for the HOT. When development costs are assumed to be similar, and a single budget holder decides on technology development, priority should be given to the development of a wound perfusion measurement tool.

Keywords: Prioritization, Multi-criteria decision analysis, Hybrid operating theater, Innovative technologies

1. INTRODUCTION

The emergence of endovascular procedures such as endovascular aneurysm repair (EVAR) and crural revascularization of peripheral aortic occlusive disease (PAOD) has changed the field of vascular surgery substantially, even though the discussion about the cost-effectiveness of these procedures is still ongoing.[1,2] Optimal imaging, technical functionality for endovascular procedures and an optimal sterile environment are achieved within a dedicated integrated theater,[3] which for many hospitals has led to the adoption of the so-called hybrid operating theater (HOT). The diffusion of the HOT has been catalyzed by several advantages of the HOT compared to the use of the standard operating theater with mobile C-arm. The following advantages have been described: a) increased field of view, translating into fewer injections and radiation exposure;[4] b) improved sensitivity and image quality; c) reduced ionizing radiation for patient and personnel; d) smart handling that simplifies positioning and accelerates the procedure; e) software for fusion of different images taken at different time points.[5] The major disadvantage of the HOT is the cost. The HOT is more expensive than a standard operating theater with mobile C-arm, mainly due to the increased size of the HOT and the expensive imaging equipment.[6,7] Initial

Send correspondence to F.G. Heslinga. E-mail: f.g.heslinga@tue.nl, Telephone: +31 (0)40 247 55 37

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research towards the value of the HOT on EVAR reported greater efficiency, reduced use of contrast agent, a reduction in received ionizing radiation and improved health outcomes.[8,9] To improve the value of the HOT even further, new innovations in the HOT have been proposed.[10]

Concurrent with research on the benefits of current HOTs, new innovative technologies for image-guided vascular surgery are being developed. Examples include tools for wound perfusion measurement, improved angiographic imaging technologies such as low field Magnetic Resonance Imaging (lfMRI) and guided steering assistance.[10,11] In the long term, these and other novel technologies could be implemented in the HOT to overcome current limitations, such as the restricted information about the perfusion of the diabetic foot ulcer of PAOD patients[12] and the still remaining dose of ionizing radiation that the patient receives during the endovascular procedures. This brings up interesting questions, such as: 1) Which innovative technologies are most likely to lead to substantially improved patient recovery times, patient health outcomes and healthcare efficiency? 2) Do these innovations offer equal value for main procedures in vascular surgery? And 3) can we prioritize new technologies to further develop, evaluate, and implement?

In this paper we propose a framework to answer these questions and thereby support decision making at different levels. If insight is gained into which innovative technology is most valuable for which patient group, time and budget spending can be prioritized to focus research and development efforts. This is not only of interest for stakeholders of the developed technology, but also for the cooperating hospitals that facilitate the developing process by investing time and money. We illustrate the use of the framework in a specific case: the new HOT in a large teaching hospital. We compare the potential added value of three completely different upcoming innovative technologies, a tool for wound perfusion measurement, improved angiographic imaging technology and guided steering assistance in a HOT environment, in three descriptive vascular procedures.

2. METHODS

The methods are divided into two sections. First, a theoretical framework is composed that is applicable to different cases. In the second part, we apply the framework to a case study.

2.1 Multi-criteria decision analysis (MCDA)

One of the standard methods to conduct early health technology assessments, is the use of MCDA methodology.[13] In an MCDA, the value of alternative technologies are estimated by scoring their performance on multiple (possibly conflicting) performance criteria. The set of criteria should be complete, non-redundant, non-overlapping, and free of preferential independence.[14] The outcome measures that are included in the criteria can be identified by literature research or through expert elicitation.

Several MCDA techniques have been developed and reviews on the use of MCDA in healthcare are available.[15,16] Each MCDA method has its own advantages and disadvantages.[13] For our case study, we used Measured Attractiveness by a Categorical Based Evaluation Technique (MACBETH).[17,18] MACBETH requires a value function for each criterion which describes the relation between value and performance data. A value score of 0 was given to clinical standard practice prior to introduction of the HOT, while the value score of 100 was defined for each criterion as the optimal future performance. To weigh the criteria, the importance of improving the value from 0 to 100 was pairwise compared between the criteria along a seven-point scale. Finally, the performance of the innovative technologies can be valued for each criterion based on measured data, evidence from literature, or expert elicitation. Given that we considered an early health technology assessment about innovative technology, the amount of available data was very limited and expert opinions were used to value the performance of the innovations. The resulting overall value of each innovative technology was calculated by summing the multiplication of value scores with weights for all performance criteria.

2.2 Portfolio analysis of different scenarios

Within the HOT several clinical procedures are performed and it can be expected that the added value of the HOT compared to a standard operating theater varies between these procedures. With the introduction of extra innovations, more value will be added to specific procedures. Therefore, it was vital to include different future scenarios in which only one or a subset of procedures was performed. In contrast to traditional scenario analysis, we did not focus on the plausibility of each scenario,[19,20] assuming that at this research phase we could use the distribution of procedures currently performed in the HOT. The MCDA was completed for each scenario (procedure). The same list of criteria was used, but the starting point and end point that define the value function of each criterion differed between procedures and thus the weight factors were likely to differ between procedures as well.

We also expected that the performances of innovative technologies regarding some criteria were affected when technologies were combined or integrated.[21] We therefore investigated the value of combined alternatives, or portfolio. Note that this type of interdependencies is not limited to cost and is not necessarily negative. One innovation might also have the potential to enable or amplify the added value of another technology.

All considerations for the MCDA were combined in a general framework, which is suitable to analyze the value of a variety of innovations to be used for different clinical procedures in the OT. An overview of the framework is shown in Figure 1.

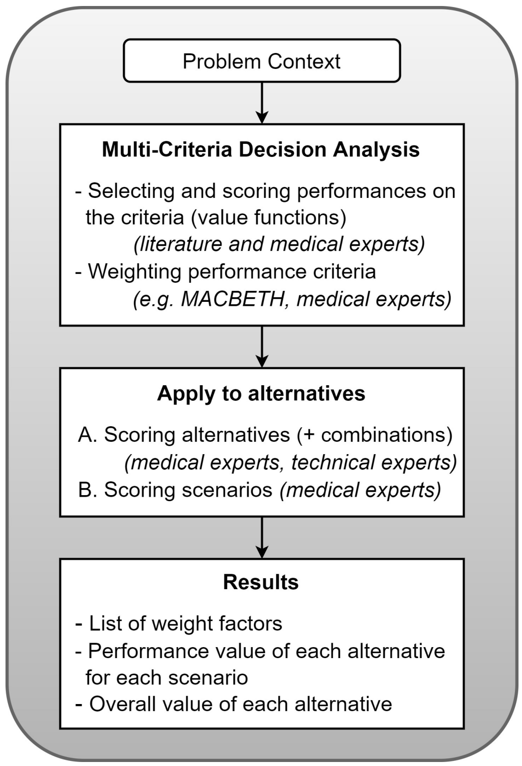

Figure 1. Framework for early health technology assessment of multiple alternatives for multiple scenarios.

3. CASE STUDY

3.1 Problem context

Medisch Spectrum Twente is a large teaching hospital in the Netherlands. The newly built HOT, (including a General Electrics Discovery IGS 740 angiography system) was brought into operation in 2016. The HOT is mainly employed for vascular surgery and in general only complete endovascular or hybrid vascular procedures were performed. Over a period of 24 weeks (January 11, 2016 to June 23, 2016) 52 EVAR and FEVAR (27%), 5 TEVAR (3%), 121 PAOD (63%) and 14 miscellaneous (7%) procedures were performed. Two vascular surgeons were interviewed to gather expert input for the MCDA. The surgeons also provided information about the requirements for future technologies. In consultation with three technical experts from the University of Twente, familiar with the suggested type of novel technologies, a set of three innovative technologies was selected.

3.2 MCDA

An initial list of outcome measures was composed based on a literature search. Health outcomes as well as efficiency outcomes were included since both are affected by the HOT.[8] After consulting with the vascular surgeons about the importance of each measure, the set performance criteria was determined (Table 1). Overlap between criteria was minimized, and health and efficiency related outcomes were mainly addressed by separate criteria.

Table 1. Performance criteria and definitions of end points

Criterion	**Description**	**Score = 100**
Ionizing Radiation	The effect of ionizing radiation that is received by personnel and patient due to fluoroscopy	No radiation
Iodine Contrast	Risks and long-time consequences for the patient due to iodine contrast	No consequences of iodine or other toxic agent
Clinical Success	Success of procedure and health implications for the patient due to intraoperative complications, postoperative complications and the medical effect of reoperations during the first year. Not including health effects due to radiation or contrast agent	Ideal situation: as maximum successful procedures as possible (with respect to very long term expectations >25 y)
Efficiency of Procedure	Required time of personnel, operation time and materials related to the whole procedure, also due to changed intraoperative complications	Ideal situation: as minimum utilization as possible (with respect to very long term expectations >25 y) of personnel, operation time and material
Financial Effect of Recovery	Direct and indirect cost of recovery period of the patient, depending on the length and type of aftercare. Also including the cost of postoperative complications and reoperations during the first year	Ideal situation: as minimum costs as reasonably possible (with respect to very long term expectations >25 y)
Ergonomics of Procedure	Ergonomic experience for surgeons and other personnel during the procedure, including ergonomic improvements due to reduced time of the procedure	No long term health effects and no discomfort from performing the procedure

MACBETH methodology required value functions to describe the range across which the performance was scored. Our preference for linear functions for this case was based on two considerations. First, we assumed vascular surgeons to make their value judgments with a linear value system in mind: Health benefits experienced by different patients can be aggregated to determine the health benefits for a group of patients. Second, interdependencies in performance would be harder to detect when non-linear value functions would be used.

Starting point of each value was a standard operating theater used in combination with a mobile C-arm. For some criteria the end point (Table 1) is clear, for example by reducing ionizing radiation to zero. For other criteria a more subjective definition was needed to describe the endpoint. All parts of the MCDA (including the criteria, value functions, scenarios, alternatives) were established during a meeting with the two vascular surgeons in which all methods of weighting and scoring using MACBETH software[17] were clarified.

To determine the weights of the criteria a Delphi-based method[22] was utilized. The importance of criteria were pairwise compared by one vascular surgeon for each scenario. The resulting weight factors (summing up to one hundred for each procedure) were proposed to the second vascular surgeon who suggested a list of adjustments. The adjustments together with the arguments, were discussed with the first surgeon and lead to the final, agreed upon, weight factors.

With the value functions in mind, the vascular surgeons independently scored (0-100) alternatives 0 to 3 for each criteria for each scenario. The net scores (subtracting the score of status quo, which is alternative 0) were summed to calculate theoretical scores for alternatives 4 to 7. These theoretical scores were then shown to the vascular surgeons to allow them to make adjustments based on expected interdependencies in the performance of the alternatives. All scores were multiplied with the weight factors to determine the value of each innovative technology for each scenario. Finally, the value of each innovative technology was multiplied with the current proportion of each procedure to calculate the overall value of each alternative. This analysis was performed for the individual scores of the surgeons as well as the average scores. In the results section, the surgeons are referred to as expert 1 and expert 2.

3.3 Scenarios

Three different scenarios were considered for the MCDA. For scenario 1, only patients that obtain crural revascularization for PAOD were included. For scenario 2, only patients that undergo EVAR or FEVAR were included. For scenario 3, only patients that undergo (branched) TEVAR were included. The number of scenarios was limited to three to keep data acquisition feasible. Therefore, EVAR and FEVAR were considered together and branched TEVAR was paired with standard TEVAR.

3.4 Alternatives & portfolio analysis

Alternatives (Table 2) were established after consulting with the two vascular surgeons and the three technical experts. Given the early developmental stage of the technologies considered we chose to describe each technology by its theoretical functionality instead of its detailed technical description. The advantage of the functional description is twofold. First, the vascular surgeons are not limited by their knowledge about the actual potential of an innovation that is yet to be developed. Second, engineers can use this framework and determine to what extent their expectations match the functional description as used in this example and thus get an idea of the current value of their technology.

The three innovative technologies in combination with the current HOT make up alternatives 1 to 3. In order to get an idea of the value of the new innovations compared to the value of the current HOT itself, the status quo was added as alternative 0. Interdependencies in performance of the innovations can be identified by combining alternatives 1 to 3 into four additional alternatives (4 to 7).

Table 2. Innovative technologies and the determined value, per procedure and overall. POAD = Peripheral aortic occlusive disease; (F)EVAR = (Fenestrated) endovascular aneurysm repair; TEVAR = Thoracic endovascular aneurysm repair

Procedure	**POAD**	**(F)EVAR**	**TEVAR**	**Overall**
Proportion	68%	29%	3%	100%
Alternatives				
0. Current HOT in Medisch Spectrum Twente	44	63	65	**49.9**
1. Alternative 0 + Wound perfusion measurement tool (perfusion measurement with a perfect indication whether measurement with a perfect indication whether blood flow is sufficient)	72	63	65	**69.1**
2. Alternative 0 + Continuous angiography with harmless contrast agent (an imaging technique that enables continuous angiography with perfect contrast, without toxic agent and that allows surgery to be performed)	60	71	72	**63.3**
3. Alternative 0 + Steering assistance of catheter ('Robotic' assistance for guidance of the catheter, that enables perfect steering inside the arteries)	58	75	78	**63.8**
4. Alternative 1+2	85	71	72	80.3
5. Alternative 1+3	85	75	78	82.2
6. Alternative 1+3	74	83	85	76.7
7. Alternative 1+2+3	94	83	85	90.4

4. RESULTS

An overview of the weights of criteria for each procedure type is shown in Figure 2. A clear trend could be identified for the priority of weights for each procedure type. The criteria clinical success and financial effect of recovery were considered to be very important, whereas ergonomics and radiation were considered less important. For the TEVAR procedure, clinical success was of extra importance in comparison with the other procedures, also due to the possibility to help certain patients for whom previously endovascular treatment possibilities were limited. Interestingly, the criterion iodine contrast was most important for PAOD patients even though their treatment did not necessarily require more contrast agent than for the (F)EVAR and TEVAR procedures. The vascular surgeons attributed the weight of this criterion to the presence of renal insufficiency, which is relatively common in patients with end-stage PAOD.[4]

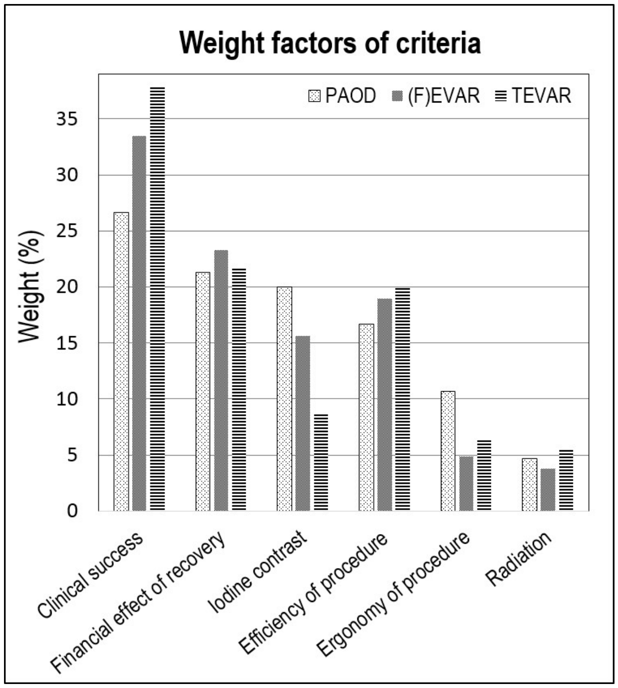

Figure 2. Weight factors of criteria for PAOD, (F)EVAR and TEVAR procedures.

Contrary to the weight factors, for which a clear consensus was reached, the performance scores given for each innovative technology varied in absolute values between the two experts. The values of alternatives 0 to 3 are shown in Figure 3. An overview of the values of all alternatives can be found in Supplementary Figure 4, which also provides the individual performance for each criterion.

Although expert 1 valued each alternative consistently higher than the other expert, both vascular surgeons agreed about general trends: Alternative 1 only adds value to the PAOD procedure, whereas the other two alternatives add value for all procedures. The experts also both concluded that for the PAOD, the introduction of a wound perfusion measurement tool would add most value to the current HOT. To consider overall value (Table 2), the current proportion of each procedure was included. Proportions were normalized as other type procedures have been left out for this analysis.

Only one interdependency in the performance of the innovative technologies was identified. Expert 1 expected that improved angiography technology and guided steering assistance would positively affect each other with respect to efficiency of scenario 1. However, due to the limited number of identified interdependencies, the alternatives 4 to 7 were not included in Figure 3.

All alternatives have the potential to add value to the current HOT, given the current distribution of procedures (Table 2). The experts value the current HOT (alternative 0) about halfway the total value scale (49.9/100)

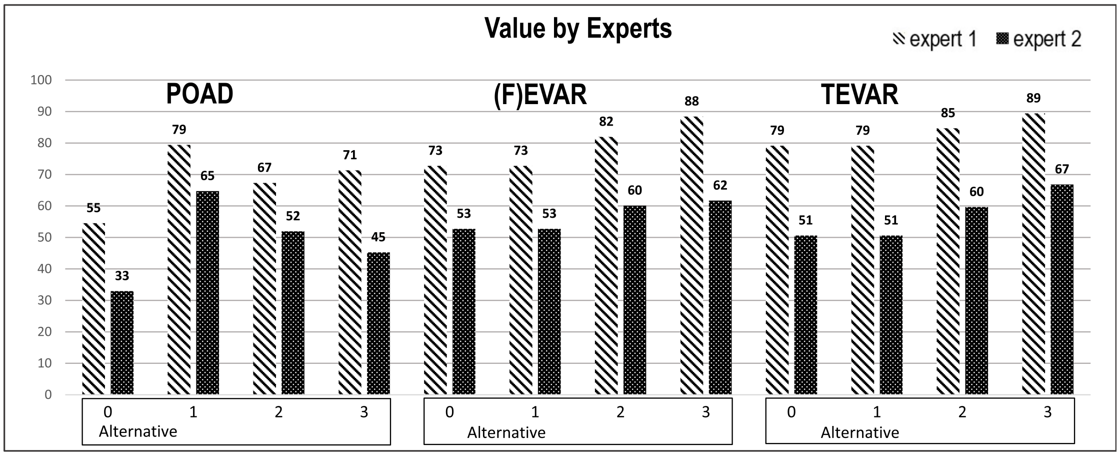

Figure 3. Performance scores of alternatives for PAOD, (F)EVAR and TEVAR.

and that alternatives 1 to 3 add between 27% and 38% to this value (63.3/100, 63.8/100 and 69.1/100 respectively). Between alternatives 1 to 3, the wound perfusion measurement tool (alternative 1) is expected to add most value (69.1/100 compared with 49.9/100), mainly due to the relatively high score for crural revascularization procedures (72/100).

5. DISCUSSION

Given the commonly high cost of development of innovative healthcare technologies, priorities need to be set for the allocation of budgets and efforts. Current evaluation of novel healthcare technology often takes place only after significant investments have already been made[23] and literature about decision support and cost-effectiveness of technologies mainly focuses on readily available healthcare technologies.[24] Specific early (economic) healthcare technology assessment reports are scarce[25,26] and a structured tool to prioritize development of innovative healthcare technologies based on evaluation in multiple scenarios is required.[27]

The MDCA framework described in this paper provides decision-making assistance for innovative technologies for vascular surgery at different levels. Primarily, engineers can evaluate whether development efforts are still likely to ultimately provide sufficient value. The value of each innovative technology has to be weighed against cost (and uncertainties) of the development process. Large organizations, leading multiple research and development projects, can use the framework to select a portfolio of technologies for further development, that is expected to offer most value. Hospitals can experience similar advantages when allocating their efforts in cooperating with developers.

In later stages, when clinical data become available, clinicians can use the scenarios to determine which combination of technologies and procedures is most valuable. With this knowledge, allocation of the HOT with integrated innovative technologies can be optimized.

Regarding the HOT we found that all three innovative technologies added substantial value on the 0 to 100 scale, while the HOT itself was found to be the most important improvement compared with the conventional operating theater with mobile C-arm situation. Of the three innovations, the wound perfusion measurement tool is expected to add most value overall. When development costs of these innovations are assumed to be similar, priority should be given to this innovation. Improved angiography technology and guided steering assistance also added substantial value, so the expected costs of further development will be crucial.

The effect of interdependencies was limited as the vascular surgeons only expected a few interactions between the three innovations. This may have been caused by the completely different nature of the technologies and the limited overlap in functionality. For other types of innovative technologies, interdependencies might manifest more clearly, and may be of interest when concerning costs. Although costs related criteria (efficiency of procedure, and financial effect of recovery) were included, the costs of implementation were not included in this research and could be a topic of future research, since combining technologies is likely to increase development costs in this context.

The combination of technologies proved to be difficult to score, as the combined scores sometimes exceeded 100, or ideal performance. The vascular surgeons always reduced the combined total to a maximum of 100. Moreover, they interpreted the expectations for the future differently, with expert 2 always giving lower scores than expert 1. One explanation may be that expert 2 has high expectations about the development of innovative stent types.[28]

For our case study only two vascular surgeons were interviewed. This provided us with limited views of the value of the innovations, especially since both surgeons were consultant in the same hospital. For a broader view, more surgeons with different affiliations could be included. Further improvements could be made by extending and synthesizing expert opinions with clinical or modeled data when these become available.

The current distribution of procedures has been used to determine overall value, but this distribution may change in the future. For example, the expected increase in prevalence of diabetes is likely to lead to more cases of PAOD[29] and in the western world there is a decline in aortic aneurysmal disease.[30] Scenarios with an updated distribution of procedures should be included in future research.

5.1 Conclusion

The present work pointed out that a MACBETH-based MCDA framework has the potential to support value-based decision making on a variety of innovative technologies in (image-guided) surgery. The current speed at which healthcare innovations are being developed requires a structured and fast evaluation method that can be applied during the development process, to ensure the efficiency of the development and implementation process. This framework supports such evaluation and supports prioritization of those innovations expected to be most valuable. In the end, the value of each innovative technology should be weighed against the cost of continuing the development process.

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PAOD		Alternative 0						Alternative 1						Alternative 2						Alternative 3					
		Current Hybrid OR Medisch																							
		Given score (0-100)						Given score (0-100)						Given score (0-100)						Given score (0-100)					
	Weights	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg
Efficiency of procedure	16,67	60	10,0	40	6,7	50	8,3	80	13,3	90	15,0	85	14,2	60	10,0	50	8,3	55	9,2	70	11,7	50	8,3	60	10,0
Financial effect of recovery	21,33	60	12,8	20	4,3	40	8,5	90	19,2	80	17,1	85	18,1	70	14,9	30	6,4	50	10,7	70	14,9	20	4,3	45	9,6
Ionizing radiation	4,67	80	3,7	50	2,3	65	3,0	90	4,2	50	2,3	70	3,3	80	3,7	60	2,8	70	3,3	90	4,2	50	2,3	70	3,3
Iodine contrast	20,00	60	12,0	45	9,0	52,5	10,5	80	16,0	45	9,0	62,5	12,5	100	20,0	100	20,0	100	20,0	80	16,0	45	9,0	62,5	12,5
Clinical success	26,67	40	10,7	40	10,7	40	10,7	80	21,3	80	21,3	80	21,3	50	13,3	50	13,3	50	13,3	60	16,0	60	16,0	60	16,0
Ergonomy of procedure	10,66	50	5,3	0	0,0	25	2,7	50	5,3	0	0,0	25	2,7	50	5,3	10	1,1	30	3,2	80	8,5	50	5,3	65	6,9
Value			**55**		**33**		**44**		**79**		**65**		**72**		**67**		**52**		**60**		**71**		**45**		**58**

(F)EVAR		Alternative 0						Alternative 1						Alternative 2						Alternative 3					
		Current Hybrid OR Medisch																							
		Given score (0-100)						Given score (0-100)						Given score (0-100)						Given score (0-100)					
	Weights	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	BG	v_E1	RM	v_E2	Average	v_avg
Efficiency of procedure	18,93	80	15,1	70	13,2	75	14,2	80	15,1	70	13,2	75	14,2	80	15,1	75	14,2	77,5	14,7	90	17,0	80	15,1	85	16,1
Financial effect of recovery	23,29	70	16,3	40	9,3	55	12,8	70	16,3	40	9,3	55	12,8	75	17,5	60	14,0	67,5	15,7	90	21,0	50	11,6	70	16,3
Ionizing radiation	3,79	80	3,0	80	3,0	80	3,0	80	3,0	80	3,0	80	3,0	80	3,0	100	3,8	90	3,4	90	3,4	85	3,2	87,5	3,3
Iodine contrast	15,65	70	11,0	80	12,5	75	11,7	70	11,0	80	12,5	75	11,7	100	15,7	85	13,3	92,5	14,5	80	12,5	80	12,5	80	12,5
Clinical success	33,49	70	23,4	40	13,4	55	18,4	70	23,4	40	13,4	55	18,4	80	26,8	40	13,4	60	20,1	90	30,1	50	16,7	70	23,4
Ergonomy of procedure	4,85	80	3,9	25	1,2	52,5	2,5	80	3,9	25	1,2	52,5	2,5	80	3,9	30	1,5	55	2,7	90	4,4	50	2,4	70	3,4
Value			**73**		**53**		**63**		**73**		**53**		**63**		**82**		**60**		**71**		**88**		**62**		**75**

TEVAR		Alternative 0						Alternative 1						Alternative 2						Alternative 3					
		Current Hybrid OR Medisch																							
		Given score (0-100)						Given score (0-100)						Given score (0-100)						Given score (0-100)					
	Weights	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	BG	v_E1	RM	v_E2	Average	v_avg
Efficiency of procedure	19,87	80	15,9	70	13,9	75	14,9	80	15,9	70	13,9	75	14,9	80	15,9	75	14,9	77,5	15,4	90	17,9	80	15,9	85	16,9
Financial effect of recovery	21,68	80	17,3	40	8,7	60	13,0	80	17,3	40	8,7	60	13,0	85	18,4	60	13,0	72,5	15,7	90	19,5	60	13,0	75	16,3
Ionizing radiation	5,41	80	4,3	80	4,3	80	4,3	80	4,3	80	4,3	80	4,3	80	4,3	100	5,4	90	4,9	95	5,1	85	4,6	90	4,9
Iodine contrast	8,63	70	6,0	80	6,9	75	6,5	70	6,0	80	6,9	75	6,5	100	8,6	85	7,3	92,5	8,0	80	6,9	85	7,3	82,5	7,1
Clinical success	37,92	80	30,3	40	15,2	60	22,8	80	30,3	40	15,2	60	22,8	85	32,2	45	17,1	65	24,7	90	34,1	60	22,8	75	28,4
Ergonomy of procedure	6,49	80	5,2	25	1,6	52,5	3,4	80	5,2	25	1,6	52,5	3,4	80	5,2	30	1,9	55	3,6	90	5,8	50	3,2	70	4,5
Value			**79**		**51**		**65**		**79**		**51**		**65**		**85**		**60**		**72**		**89**		**67**		**78**

Combined alternatives

PAOD		Alternative 4						Alternative 5						Alternative 6						Alternative 7					
		Alternatives 0 + 1 + 2						Alternatives 0 + 1 + 3						Alternatives 0 + 2 + 3						Alternative 0 + 1 + 2 + 3					
		Given (adjusted) score (0-100)						Given (adjusted) score (0-100)						Given (adjusted) score (0-100)						Given (adjusted) score (0-100)					
	Weights	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg
Efficiency of procedure	16,67	80	13,3	100	16,7	90	15,0	90	15,0	100	16,7	95	15,8	90	15,0	60	10,0	75	12,5	90	15,0	100	16,7	95	15,8
Financial effect of recovery	21,33	100	21,3	90	19,2	95	20,3	100	21,3	80	17,1	90	19,2	80	17,1	30	6,4	55	11,7	100	21,3	90	19,2	95	20,3
Ionizing radiation	4,67	90	4,2	60	2,8	75	3,5	90	4,2	50	2,3	70	3,3	90	4,2	60	2,8	75	3,5	100	4,7	60	2,8	80	3,7
Iodine contrast	20,00	100	20,0	100	20,0	100	20,0	90	18,0	45	9,0	67,5	13,5	100	20,0	100	20,0	100	20,0	100	20,0	100	20,0	100	20,0
Clinical success	26,67	80	21,3	90	24,0	85	22,7	100	26,7	100	26,7	100	26,7	70	18,7	70	18,7	70	18,7	100	26,7	100	26,7	100	26,7
Ergonomy of procedure	10,66	50	5,3	10	1,1	30	3,2	80	8,5	50	5,3	65	6,9	80	8,5	60	6,4	70	7,5	80	8,5	60	6,4	70	7,5
Value			**86**		**84**		**85**		**94**		**77**		**85**		**83**		**64**		**74**		**96**		**92**		**94**

(F)EVAR		Alternative 4						Alternative 5						Alternative 6						Alternative 7					
		Alternatives 0 + 1 + 2						Alternatives 0 + 1 + 3						Alternatives 0 + 2 + 3						Alternative 0 + 1 + 2 + 3					
		Given (adjusted) score (0-100)						Given (adjusted) score (0-100)						Given (adjusted) score (0-100)						Given (adjusted) score (0-100)					
	Weights	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg
Efficiency of procedure	18,93	80	15,1	75	14,2	77,5	14,7	90	17,0	80	15,1	85	16,1	90	17,0	85	16,1	87,5	16,6	90	17,0	85	16,1	87,5	16,6
Financial effect of recovery	23,29	75	17,5	60	14,0	67,5	15,7	90	21,0	50	11,6	70	16,3	95	22,1	70	16,3	82,5	19,2	95	22,1	70	16,3	82,5	19,2
Ionizing radiation	3,79	80	3,0	100	3,8	90	3,4	90	3,4	85	3,2	87,5	3,3	95	3,6	100	3,8	97,5	3,7	95	3,6	100	3,8	97,5	3,7
Iodine contrast	15,65	100	15,7	85	13,3	92,5	14,5	80	12,5	80	12,5	80	12,5	100	15,7	85	13,3	92,5	14,5	100	15,7	85	13,3	92,5	14,5
Clinical success	33,49	80	26,8	40	13,4	60	20,1	90	30,1	50	16,7	70	23,4	100	33,5	50	16,7	75	25,1	100	33,5	50	16,7	75	25,1
Ergonomy of procedure	4,85	80	3,9	30	1,5	55	2,7	90	4,4	50	2,4	70	3,4	90	4,4	55	2,7	72,5	3,5	90	4,4	55	2,7	72,5	3,5
Value			**82**		**60**		**71**		**88**		**62**		**75**		**96**		**69**		**83**		**96**		**69**		**83**

TEVAR		Alternative 4						Alternative 5						Alternative 6						Alternative 7					
		Alternatives 0 + 1 + 2						Alternatives 0 + 1 + 3						Alternatives 0 + 2 + 3						Alternative 0 + 1 + 2 + 3					
		Given (adjusted) score (0-100)						Given (adjusted) score (0-100)						Given (adjusted) score (0-100)						Given (adjusted) score (0-100)					
	Weights	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg	E1	v_E1	E2	v_E2	Average	v_avg
Efficiency of procedure	19,87	80	15,9	75	14,9	77,5	15,4	90	17,9	80	15,9	85	16,9	90	17,9	85	16,9	87,5	17,4	90	17,9	85	16,9	87,5	17,4
Financial effect of recovery	21,68	85	18,4	60	13,0	72,5	15,7	90	19,5	60	13,0	75	16,3	95	20,6	80	17,3	87,5	19,0	95	20,6	80	17,3	87,5	19,0
Ionizing radiation	5,41	80	4,3	100	5,4	90	4,9	95	5,1	85	4,6	90	4,9	95	5,1	100	5,4	97,5	5,3	95	5,1	100	5,4	97,5	5,3
Iodine contrast	8,63	100	8,6	85	7,3	92,5	8,0	80	6,9	85	7,3	82,5	7,1	100	8,6	90	7,8	95	8,2	100	8,6	90	7,8	95	8,2
Clinical success	37,92	85	32,2	45	17,1	65	24,7	90	34,1	60	22,8	75	28,4	95	36,0	65	24,7	80	30,3	95	36,0	65	24,7	80	30,3
Ergonomy of procedure	6,49	80	5,2	30	1,9	55	3,6	90	5,8	50	3,2	70	4,5	90	5,8	55	3,6	72,5	4,7	90	5,8	55	3,6	72,5	4,7
Value			**85**		**60**		**72**		**89**		**67**		**78**		**94**		**76**		**85**		**94**		**76**		**85**

Figure 4. Overview of all weights and scores of the performance criteria. E1 = Expert 1, v_E1 = score given by expert 1. E2 = Expert 2, v_E2 = score given by expert 2.