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FULL PAPER

Hospital costs and cosmetic outcome of benign and high-risk breast lesions managed by vacuum-assisted excision versus surgical excision

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Objectives: Although vacuum-assisted excision (VAE) is a safe and effective alternative to surgical excision (SE), the latter is most commonly used for the management of benign and high-risk breast lesions. To evaluate the healthcare benefit of VAE, hospital costs and cosmetic outcome after VAE were compared to SE. Additionally, the impact of VAE implementation on hospital costs was investigated.
Methods: This was a single-centre retrospective cohort study with two cohorts: "VAE" and "SE". All patients with a benign or high-risk lesion excised by VAE or SE from January 2016 up to December 2019 were included. Cosmetic outcome was measured with the BCTOS-cosmetic subscale, and hospital costs were presented as mean (SD) and median (IQR).
Results: During the study period, 258 patients with 295 excised lesions were included. The initial procedure was VAE in 102 patients and SE in 156 patients. Hospital costs after (median € 2324) were significantly lower than before (median € 3,144) implementation of VAE (mean difference € 1,004, $p < 0.001$), most likely attributable to the lower costs for patients treated with VAE (mean difference € 1,979, $p < 0.001$). Mean cosmetic outcome was comparable between VAE (median 1.35) and SE (median 1.44, $p = 0.802$).
Conclusions: Implementing VAE as an alternative treatment option for benign and high-risk breast lesions resulted in a large decrease in hospital costs but a cosmetic benefit of VAE could not be demonstrated in this retrospective study.
Advances in knowledge: Costs associated with the complete patient pathway were included and not only VAE was compared to SE but also the before cohort was compared to the after cohort to demonstrate the benefit of VAE implementation in clinical practice. Additionally, cosmetic outcome was compared between VAE and SE using patient reported outcome measures.

INTRODUCTION

In the Netherlands, approximately 17,000 women are diagnosed with breast cancer each year. Even more females are diagnosed with benign or high-risk breast lesions,[1–4] although exact prevalence data are lacking. Excision of these lesions is only indicated if it is symptomatic or for diagnostic purposes.[5–8] Surgical excision (SE) is still the most performed procedure for benign or high-risk breast lesions in the Netherlands. However, previous studies have shown that vacuum-assisted excision (VAE) is an alternative non-surgical treatment option for most of these lesions.[9–11]

With VAE, the tumour is removed under ultrasound guidance, using a large core needle that excises multiple tissue samples, without causing a surgical scar.[8] High complete excision rates (>94%) and low complication rates (5%) are reported for VAE, with similar diagnostic accuracy as SE.[9,12] A good cosmetic outcome was reported in 73.9% of patients after VAE.[13] Compared to the cosmetic outcome reported in literature after SE, the cosmetic outcome after VAE was better.[14,15] Only one comparative study was previously published in which a higher satisfaction with breast appearance was reported in patients treated with VAE for a benign lesion using a single question.[16] However, a

comparative study on cosmetic outcome for patients with benign and high risk lesions using a validated questionnaire has not yet been performed.

Although lower costs and a better cosmetic outcome are assumed after VAE compared to SE in previous studies,[9,16–21] only one recent study investigated the procedural costs of VAE and SE.[22] In this study, the VAE procedure itself was shown to be less expensive than SE ($1348 versus $3101), but a cost-effectiveness analysis including costs of all visits and investigations in follow-up and re-interventions to treat complications is lacking. Moreover, not all lesions are suitable for VAE due to its location (in proximity to the skin or retro areolar lesions), entity (papillary lesions or phyllodes tumours) or size (>5 cm).[23–28] An evaluation of hospital costs and cosmetic outcome of current practice (after implementation of VAE) will provide a more relevant overview of cost savings in daily practice for centres considering to add VAE to their treatment options.

This study focuses on the cosmetic outcome and hospital costs of the total patient pathway of patients treated with VAE and SE for benign and high-risk breast lesions. Additionally, the impact of implementation of VAE as new treatment option on overall hospital costs in the management of this patient population will be analysed. It is hypothesised that VAE will be more cost-effective than SE and patients will experience a better cosmetic outcome when managed with VAE compared to SE, for the management of benign and high-risk breast lesions.

METHODS

Design and patients

This was a single centre retrospective cohort study performed in a large teaching hospital in the Netherlands with a breast clinic treating approximately 350 new patients with breast lesions a year. VAE was introduced in this hospital as a management option for benign and high-risk lesions in July 2017. Included were all females (≥16 years) with an excision for a benign or high-risk breast lesion through VAE or SE from January 2016 up to December 2019. Excluded were patients who opted out (n = 3), with a concomitant diagnosis of breast cancer (n = 1) or DCIS (n = 2), a BI-RADS five lesion (n = 7), ductectasia without a lesion on imaging (n = 8), mastitis (n = 13), and when only a first-line vacuum-assisted biopsy (VAB) was performed but no VAE (n = 1). Patients who were treated for a benign or high-risk breast lesion before 2016 were also excluded (n = 13). Additionally excluded for the analysis of cosmetic outcome were patients who did not speak Dutch (n = 3), had bilateral lesions (n = 9), had a mastectomy (n = 1) or died of a glioblastoma (n = 1) before the questionnaires were send. All included lesions were categorised according to the Dutch guideline into benign or high-risk lesions (table A.1,Supplementary Material 1).[24]

Indication for excision

In line with the Dutch guideline, patients with benign lesions are generally reassured and discharged. In case of fear for malignancy, symptoms or an uncertain diagnosis (*e.g.,* PT could not be excluded) excision was considered. According to the Dutch Guideline, high-risk breast lesions should be managed as follows: repeated biopsy, diagnostic excision, or follow-up with mammography or ultrasound.[24] The choice between VAE or SE was discussed in a multidisciplinary team meeting with the radiologist, pathologist, and surgical oncologist. Overall, SE was preferred in papillary lesions and phyllodes tumours, to obtain intact specimen and clear margins, respectively. SE was also preferred if there was a high suspicion of DCIS or malignancy. All other high-risk and benign lesions were considered for VAE. Technically unfit for VAE were lesions with a size >5 cm, highly mobile lesions, and lesions in close proximity of the skin, areolar complex or pectoralis muscle at the discretion of the radiologist. The vast majority of lesions, including all BI-RADS 3 and 4 lesions were preceded by a core needle biopsy.

Outcomes

Patient reported cosmetic outcome was measured using the cosmetic subscale of the Dutch Breast Cancer Treatment Outcome Scale (BCTOS-cs).[13,15] This questionnaire has nine items, scoring each item on the perceived difference between the treated and the untreated breast on a scale of one (no difference) to four (big difference). Additionally, patients who underwent both procedures were asked which procedure was preferred for any future lesions.

Hospital costs were calculated per healthcare activity as weighted benchmark costs over 2019 in which the costs of 2018 were used as a baseline. Included in these benchmark prices are salary costs adjusted for treatment duration, material costs and fixed charges such as depreciation of equipment. The overall cost accounting process includes allocating total costs of the hospital based on distribution keys to departments and ultimately to healthcare activities.

Excision procedures

VAE procedures were performed by breast radiologists at the outpatient clinic of our radiology department under local anaesthesia. The lesion was targeted and excised under real-time ultrasound guidance with The ENCOR ULTRA® Breast Biopsy System in combination with a 7 Gauge needle. When no residual lesion could be identified on ultrasound, the excision was considered complete. Treatment duration was approximately 15–45 min depending on lesion size. A marker was placed after VAE and the position of the marker was checked with mammography. The goal of the VAE was to achieve complete excision and/or obtain sufficient material for final diagnosis of the lesion.

SE was performed in the operating room under general anaesthesia in day surgery. Tumour localisation was used if the lesion was not palpable. The choice of skin incision was at the surgeons' discretion. Treatment duration per patient was approximately 60 min.

Data collection

All eligible patients who underwent breast surgery or VAE in the study period were identified based on diagnose code "317 benign breast disease" from the electronic patient records. Additionally, all breast biopsy results were checked for any missed patients fulfilling the inclusion criteria.

Table 1. Unit costs

Health care activity per category	Unit cost
Procedure	
Sentinel node procedure	€ 305
Sentinel node procedure open	€ 930
Partial breast excision	€ 1,009 - € 1,380
Mastectomy	€ 1922
Vacuum assisted excision	€ 203
Procedure related	
Inpatient hospital day	€ 351 - € 512
Preparation for anaesthesia (nerve block, local injections, peripheral IV)	€ 35 - € 199
Radiology	
Breast ultrasound	€ 70
Breast biopsy	€ 121
Mammography	€ 91
Localisation of the tumour	€ 205
Axillary ultrasound	€ 84
Breast MRI	€ 208
Intraoperative specimen assessment	€ 56
US guided drainage (cyste, abscess, etc)	€ 109 - € 167
Pathology	
Specimen assessment	€ 382 - € 623
Biopsy or cytology assessment	€ 56 - € 143
Other	
Blood tests or pus cultures	€ 1 - € 23
Hospital visits	
First visit	€ 183
Follow-up visit	€ 95
Multidisciplinary team meeting	€ 57

Patient, tumour, and procedural characteristics were abstracted from the electronic patient records. If more than one lesion per patient was resected, the tumour size at diagnosis is presented as the largest diameter per patient, and the highest category for tumour type and BI-RADS classification was presented. The term re-excision includes an excision because of upgrading to a malignancy after SE or VAE as well as a re-excision because of previous incomplete excision or because of a recurrent lesion. All disease related healthcare activities from half a year before the procedure up to February 2021 were automatically collected from the electronic patient record. The number of outpatient visits was manually collected from the electronic patient record due to incomplete automatic data. Corresponding hospital costs are given in Table 1.

Sample size calculation and statistical analyses

Sample size calculation was based on the analysis of the cosmetic outcome. To correct for skewness of data, the logistic transposed outcome on the BCTOS-cs was used for the power calculation,[13] which was 0.39 (SD 0.28) after VAE for benign lesions and 0.64 (SD 0.34) after SE for early stage breast cancer.[13,15] To correct for the lack of radiotherapy after excision of benign and high-risk breast lesions, a value of 0.55 was used for the cosmetic outcome after SE in this study. To demonstrate superiority in cosmetic outcome of VAE with a power of 90% (10% β error) and a significance level of 5% (α), 49 patients per arm of the study cohort are required. Assuming a response rate of 73% at least 134 patients should be contacted.[13]

Because data distribution did not follow a normal law, baseline characteristics are summarised with median (range) and n (%) for categorical variables. Cosmetic outcome is measured as an unweighted mean on the BCTOS-cs and categorised as proposed by Hennigs et al into good, intermediate, fair or poor.[29] Hospital costs were presented as mean (SD) and median (IQR). The differences between cohorts (before versus after, VAE versus SE) were evaluated using a Mann-Whitney U test for continuous data, and with a Chi-square or Fisher's Exact test depending on the numbers per cell for the categorised cosmetic outcome. Multiple regression was performed to correct for variables that were statistically significantly different at baseline. All analyses were performed using IBM SPSS 27 (IBM Corp. Armonk, NY) and $p < 0.05$ (two-sided) was considered statistically significant. Missing data only occurred in baseline characteristics and were handled using pairwise deletion, see also Table 2.

If more high-risk lesions would be treated by means of VAE in the future, a higher rate of SE after VAE because of upstaging to DCIS or IC is expected. To calculate if VAE would still be cost-effective with an increasing re-excision rate, a hypothetical model was plotted. This model was based on the mean costs of patients in whom the lesion was excised through SE (€ 3,506.10), VAE with subsequent SE (€ 4,774.64), and VAE without subsequent SE (€ 1,675.85). Based on the upstaging rates in this patient population, a higher re-excision rate than 20% is not expected.[6,11,26,27,30–33] Therefore, an upper limit of 20% was chosen in the figure of the model. Only patients in whom one lesion was excised were included in this model ($n = 239$).

Ethical approval

The study protocol was reviewed by the institutional reviewing board of our hospital (advisory committee on science (ACW)) and an ethical waiver was granted. This study was conducted in accordance with the Declaration of Helsinki.

RESULTS

Baseline characteristics

A total of 256 patients with 290 excised lesions in 277 procedures were included for analysis. The initial procedure was VAE in 101 patients and SE in 155 patients (Table 2). After implementation of VAE, 64% ($n = 100$) of all benign lesions and 28% ($n = 12$) of all high-risk lesions were excised by means of VAE. The remaining lesions were surgically excised. Baseline characteristics of the study population are presented in Table 2.

Table 2. Baseline characteristics per patient for the before versus after, and the VAE versus SE cohort

	Before $n = 83$	After $n = 173$		SE $n = 155$	VAE $n = 101$	
	n (%)	n (%)	*P*-value	n (%)	n (%)	*P*-value
Age, years[a]	36 (29–48)	38 (25–48)	0.635[b]	41 (28–50)	35.0 (25–43)	**0.006**[b]
Tumour size (largest), mm[a]	20 (13–29)	19 (11–26)	0.141[b]	21 (13–30)	16 (11–22)	**0.005**[b]
≤2 cm	43 (51.8)	95 (54.9)	0.688[c]	75 (48.4)	63 (62.4)	**0.029**[c]
>2 cm	39 (47.0)	77 (44.5)		79 (51.0)	37 (36.6)	
Missing	1 (1.2)	1 (0.6)		1 (0.6)	1 (1.0%)	
BCTOS-cs completed ($n = 242$)						
Yes	48 (60.0)	110 (67.9)	0.411[c]	89 (60.5)	69 (72.6)	0.072[c]
No	32 (40.0)	52 (32.1)		58 (39.5)	26 (27.4)	
Time from procedure to questionnaire, months[a] ($n = 158$)	45 (42–49)	13 (8–18)	**<0.001**[b]	36 (21–46)	12 (8–15)	**<0.001**[b]
Time from first to last health care activity, months[a]	12 (2–39)	4 (2–13)	**0.002**[b]	6 (2–26)	4 (1–12)	**0.003**[b]
Reason of referral						
New lesions, pain or growing lesion	71 (85.5)	149 (86.1)	0.433	128 (82.6)	92 (91.1%)	0.153
Screening abnormalities	12 (14.5)	21 (12.1)		25 (16.1)	8 (7.9)	
Follow-up for known lesion	-	3 (1.7)		2 (1.3)	1 (1.0)	
Lesion type before excision						
Benign lesions	53 (63.9)	127 (73.4)	0.097	93 (60.0)	87 (86.1)	**<0.001**
High-risk lesion	30 (36.1)	43 (24.9)		61 (39.4)	12 (11.9)	
Other	-	3 (1.7)		1 (0.6)	2 (2.0)	
Lesion type after excision						
Benign lesions	52 (62.7)	122 (70.5)	0.174	87 (56.1)	86 (85.1)	**<0.001**
High-risk lesion	26 (31.3)	46 (26.6)		59 (38.1)	13 (12.9)	
DCIS	4 (4.8)	3 (1.7)		6 (3.9)	1 (1.0)	
Malignant	1 (1.2)	-		1 (0.6)	-	
Other	-	2 (1.2)		2 (1.3)	1 (1.0)	
BI-RADS classification on imaging						
0	-	1 (0.6)	0.784	1 (0.6)	-	**0.006**
II	13 (15.7)	25 (14.5)		19 (12.3)	19 (18.8)	
III	33 (49.8)	79 (45.7)		58 (37.4)	54 (53.5)	
IV	34 (41.0)	66 (38.2)		73 (47.1)	27 (26.7)	
Unknown	3 (3.6)	2 (1.2)		4 (2.6)	1 (1.0)	
Number of resected tumours per patient						

(Continued)

Table 2. (Continued)

	Before $n = 83$	After $n = 173$		SE $n = 155$	VAE $n = 101$	
	n (%)	n (%)	*P*-value	n (%)	n (%)	*P*-value
1	77 (92.8)	162 (93.6)	0.838	144 (92.9)	95 (94.1)	0.383
2	5 (6.0)	7 (4.0)		7 (4.5)	5 (5.0)	
3	1 (1.2)	2 (1.2)		3 (1.9)	-	
5	-	1 (0.6)		-	1 (1.0)	
>5	-	1 (0.6)		1 (0.6)	-	
Nmber of procedures per patient (including re-excisions)						
1	78 (94.0)	159 (91.9)	0.590	143 (92.3)	94 (93.1)	0.515
2	5 (6.0)	12 (6.9)		10 (6.5)	7 (6.9)	
3	-	2 (1.2)		2 (1.3)	-	
Type of procedure						
Only SE	82 (98.8)	70 (40.5)	**<0.001**	152 (98.1)	-	**<0.001**
Only VAE	-	98 (56.6)		-	98 (97.0)	
Both	1 (1.2)	5 (2.9)		3 (1.9)	3 (3.0)	
Upgrade to DCIS or IC						
Yes	5 (6.0)	3 (1.7)	0.117[c]	7 (4.5)	1 (1.0)	0.152[c]
No	78 (94.0)	170 (98.3)		148 (95.5)	100 (99.0)	
Complications						
Yes	2 (2.4)	12 (6.9)	0.238[c]	6 (3.9)	8 (7.9)	0.173[c]
No	81 (97.6)	161 (93.1)		149 (96.1)	93 (92.1)	

DCIS, ductal carcinoma in situ; SE, surgical excision; VAE, vacuum assisted excision; mm, millimetre.
Values in parentheses are percentages, unless indicated otherwise: [a] values are median (IQR).
P-values are Chi-square test, unless indicated otherwise: [b] Mann-Whitney U test, [c] Fisher Exact.
[d]Excluding patients specifically excluded of cosmetic analysis (see methods).
[e]Per patient, if more lesions were excised in one patient, most severe lesion type or highest BI-RADS category is shown.
[f]Other includes a granular cell tumour, intramammary lymphe node, and no abnormality and thus no explanation for BI-RADS classification in this biopsy.

Cost analysis

The largest proportion of hospital costs are made within the first eight months after the first health care activity (Figure A.1, Supplementary Material Supplementary Figure 1). Although the time between the first and last healthcare activity was significantly different between cohorts, it is expected that the differences in hospital costs are attributable to the first months of provided health care.

If patients were initially treated with VAE (median € 1,585.66), the total costs of the patient pathway were significantly lower when patients were initially treated with SE (median € 3,244.85, $p < 0.001$)(Table 3a), also after correction for differences in baseline characteristics ($\beta = -0.507$, $p < 0.001$).

Implementation of VAE led to a significant decrease of total hospital costs per patient when treated for a benign or high-risk lesions. Median costs per patient were € 3,144.29 in the before cohort and € 2,324.07 in the after cohort ($p < 0.001$)(Table 3b), also after correction for baseline characteristics ($\beta = 0.217$, $p < 0.001$). Similar results were found for the subgroup of patients in which only one lesion was excised (data not shown).

Hospital costs per lesion type

The difference between the VAE versus SE cohort was significant for both benign and high-risk lesions but not when DCIS or IC was found after excision (Table 4). The cost difference for both benign and high-risk lesions remained statistically significant when lesions were categorised based on lesion type at diagnosis and for the subgroup of patients in which only one lesion was excised ($n = 239$)(data not shown).

Prediction model

In this study, the overall re-excision rate and overall upgrade rate is 3.5 and 3.1%, respectively. If in the future, a higher proportion of high risk lesions are treated with VAE, this might result

Table 3. a. Differences in hospital costs per patient per category for the SE versus VAE cohort. b. Differences in hospital costs per patient per category for the before versus after cohort

Category	SE $n = 155$	VAE $n = 101$	P-value[a]
Procedure (median, IQR)	€ 1,380.46 (1,009.03–1,380.46)	€ 203.15 (202.15–203.15)	**<0.001**
(mean, SD)	€ 1,319.56 (473.06)	€ 264.20 (256.22)	
Procedure related (median, IQR)	€ 348.54 (348.54–348.54)	-	**<0.001**
(mean, SD)	€ 335.99 (203.52)	€ 30.28 (143.79)	
Radiology (median, IQR)	€ 582.73 (300.51–912.62)	€ 578.51 (457.38–858.23)	0.223
(mean, SD)	€ 642.43 (418.12)	€ 684.82 (344.38)	
Pathology (median, IQR)	€ 525.25 (525.25–668.66)	€ 286.81 (143.41–525.25)	**<0.001**
(mean, SD)	€ 572.67 (213.77)	€ 370.40 (285.23)	
Outpatient visits (median, IQR)	€ 581.46 (429.79–853.39)	€ 391.92 (297.15–581.46)	**<0.001**
(mean, SD)	€ 681.12 (356.55)	€ 471.51 (218.83)	
Other (median, IQR)	-	-	0.355
(mean, SD)	€ 0.91 (8.32)	€ 0.52 (3.44)	
Total (median, IQR)	€ 3,244.85 (2,928.39–3,863.17)	€ 1,585.66 (1,308.72–1,991.88)	**<0.001**
(mean, SD)	€ 3,552.70 (1,095.73)	€ 1,821.73 (903.02)	
Category	**Before $n = 83$**	**After $n = 173$**	**P-value[a]**
Procedure (median, IQR)	€ 1,380.46 (1,009.03–1,380.46)	€ 203.15 (203.15 - 1009.03)	**<0.001**
(mean, SD)	€ 1,318,86 (270.05)	€ 703.76 (690.20)	
Procedure related (median, IQR)	€ 348.54 (35.51–348.54)	€ 0.00 (0.00–348.54)	**<0.001**
(mean, SD)	€ 262.88 (187.21)	€ 192.59 (253.02)	
Radiology (median, IQR)	€ 449.35 (282.22–839.59)	€ 648.22 (450.35–890.17)	**0.014**
(mean, SD)	€ 594.15 (438.48)	€ 690.34 (362.55)	
Pathology (median, IQR)	€ 525.25 (438.23–525.25)	€ 525.25 (286.81–525.25)	**0.004**
(mean, SD)	€ 533.92 (201.48)	€ 473.17 (286.71)	
Outpatient visits (median, IQR)	€ 524.56 (391.92–846.75)	€ 524.56 (372.89–726.94)	0.296
(mean, SD)	€ 655.74 (422.58)	€ 570.93 (264.21)	
Other (median, IQR)	-	-	0.560
(mean, SD)	€ 1.09 (10.00)	€ 0.59 (4.60)	
Total (median, IQR)	€ 3,144.29 (2,636.71–3,695.39)	€ 2,324.07 (1,493.43–3,286.74)	**<0.001**
(mean, SD)	€ 3,366.66 (990.51)	€ 2,631.39 (1,403.68)	

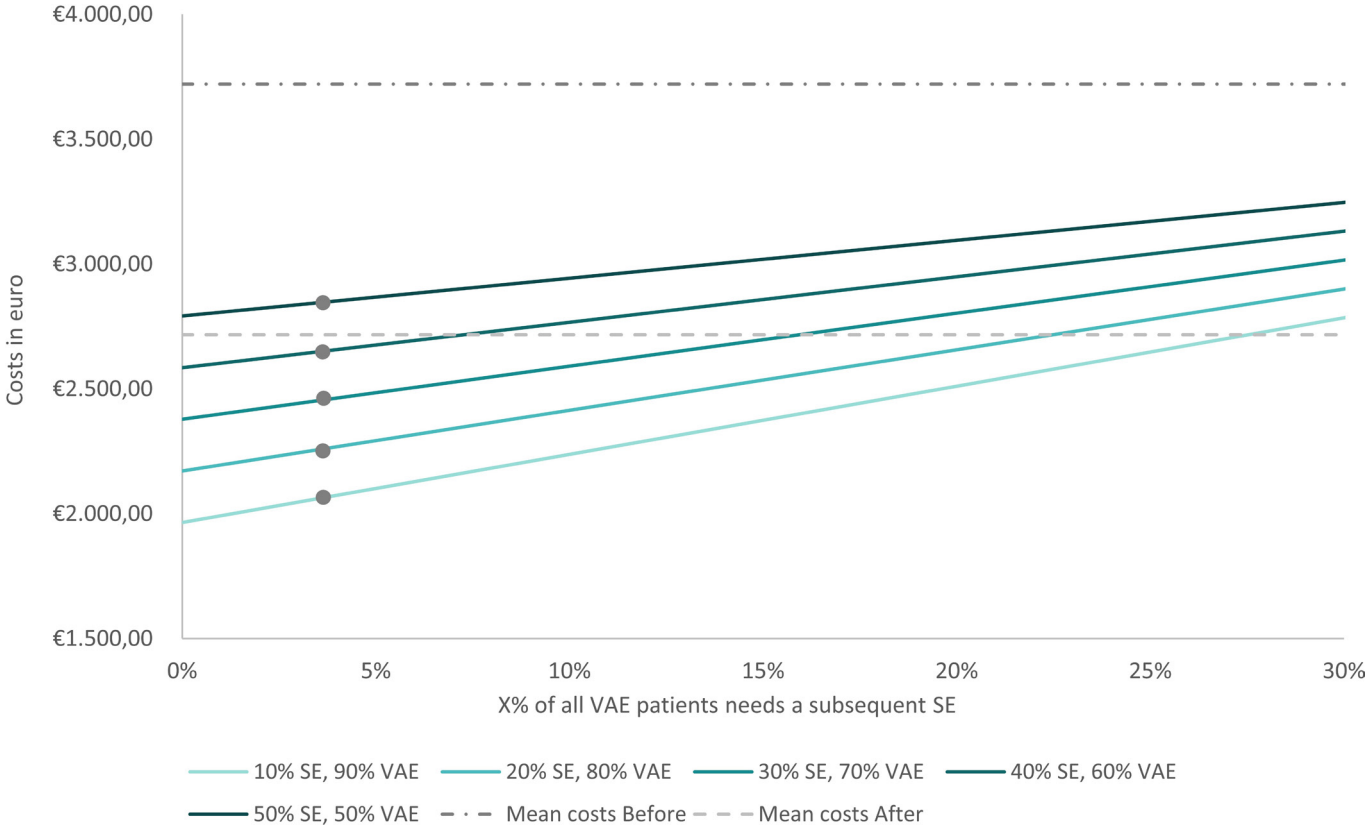
IQR, interquartile range; SD, standard deviation; SE, surgical excision; VAE, vacuum assisted excision.
[a]Mann-Whitney U test.

Table 4. Total hospital costs per patient per lesion subtype diagnosed after excision in the SE versus VAE cohort

	SE $n = 156$	VAE $n = 102$	P-value[a]
Benign/other[b] (median, IQR)	€ 3,039.88 (2,717 - 3,540)	€ 1,497 (1,278 - 1,839)	**<0.001**
(mean, SD)	€ 3,256.59 (850.86)	€ 1,707.08 (797.07)	
High-risk (median, IQR)	€ 3,511.90 (3,194 - 3,979)	€ 2,095.78 (1,850 - 2,419)	**<0.001**
(mean, SD)	€ 3,780.59 (984.67)	€ 2,400.35 (1,132.66)	
DCIS/IC (median, IQR)	€ 4,383.47 (4,116 - 6,738)	€ 4,274.72 (-)	>0.999
(mean, SD)	€ 5,396.73 (2,246.53)	€ 4,274.72 (-)	

IQR, interquartile range; SD, standard deviation; SE, surgical excision; VAE, vacuum assisted excision.
[a]Mann-Whitney U test.
[b]Other includes a granular cell tumour and a intramammary lymphe node.

Figure 1. Costs in euros are plotted against the proportion of patients treated with VAE which need a subsequent SE. The different lines represent the proportion of patients treated with VAE and SE and the grey dots represent a re-excision rate of 3.5%.



in a higher re-excision rate after VAE. Even if the re-excision rate would rise, hospital costs will be lower, independent of the proportion of patients treated with VAE (Figure 1). The break-even point was calculated at a re-excision rate of 68% which is considered unrealistic in this patient population.

Cosmetic outcome and patient satisfaction

The BCTOS-cs was completed by 158 of 242 patients (65%). The response rate for patients after SE (61%, $n = 89$) was not significantly lower than for patients after VAE (73%, $n = 69$, $p = 0.072$). No significant difference was found for mean cosmetic outcome between the VAE (median 1.38) and SE cohort (median 1.44, $p = 0.692$), nor after correcting for baseline differences ($\beta = -0.138$, $p = 0.307$). Categorised cosmetic outcome was also comparable between the VAE (good 73%, intermediate 22%, fair 6%) and SE (good 79%, intermediate 16%, fair 6%) cohort ($p = 0.618$). Breast tenderness and swelling were more often absent after SE than after VAE; no difference in, respectively, 64 versus 45% ($p = 0.043$) and 88 versus 69%, ($p = 0.018$). On the other hand, nipple appearance was better after VAE than after SE (no difference in 97 vs 74% $p = 0.001$)(Figure 2).

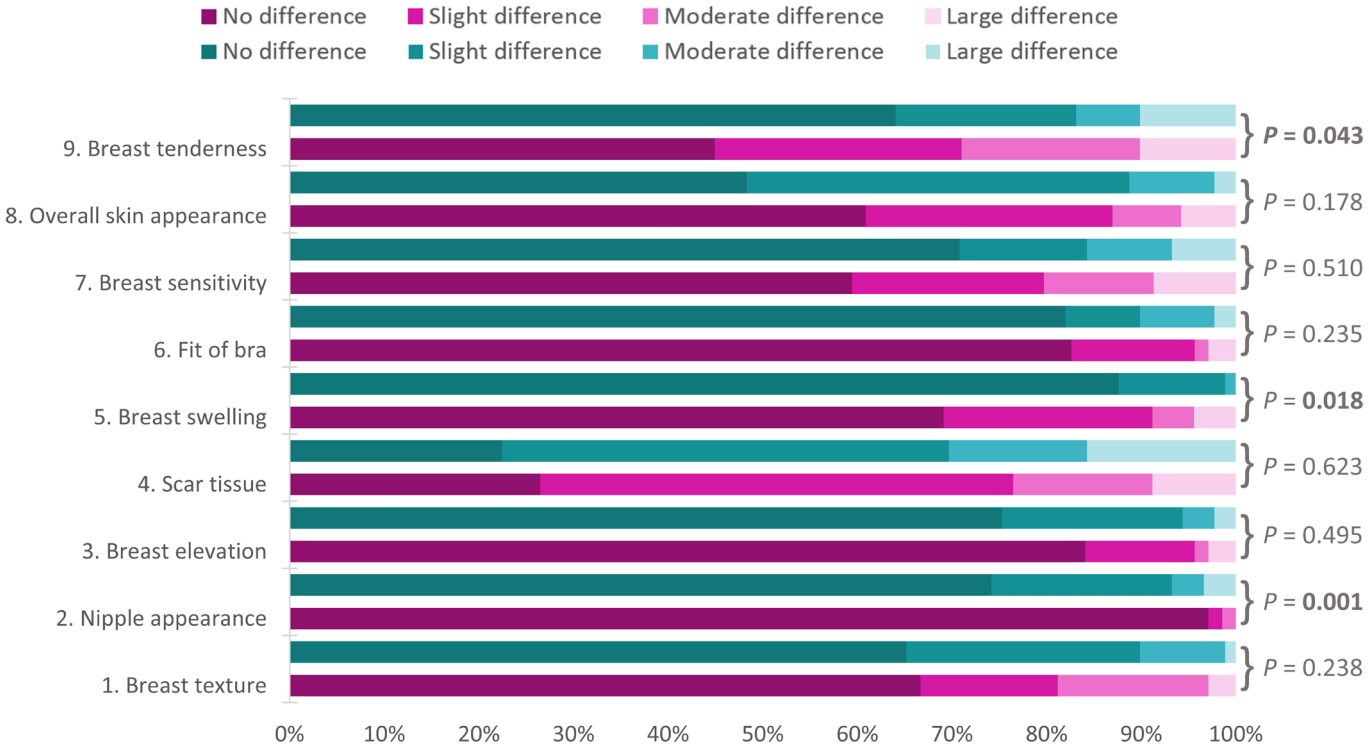
Six out of eight patients who had undergone both procedures could be reached to answer questions on patient satisfaction. Four of them would choose VAE over SE if they had a new lesion. Reasons to choose for VAE were faster recovery, no risks associated with general anaesthesia, a smaller scar, less invasive and shorter procedure. The other two patients would prefer SE due to the more secure feeling of complete excision, preference of not being awake, and to avoid the hematoma after VAE.

DISCUSSION

Total hospital costs for patients with benign and high-risk breast lesions excised by means of VAE are significantly lower than for patients in which lesions were excised through SE. The introduction of VAE resulted in a significant decrease of median costs per patient from € 3,367 to € 2,631. The expected better cosmetic outcome after VAE than after SE could not be demonstrated but was comparable between the two procedures.

For benign lesions, previous studies have shown that VAE is a safe and effective alternative for SE in an outpatient setting.[9,12,17,18,21,34–37] Additionally, VAE is increasingly being used for the excision of high-risk lesions.[6,11,22,24–28,38–41] This is also reflected in this study in which VAE is used for a relative small proportion of excisions for high-risk lesions and a relative large proportion of excisions for benign lesions. Although routine excision of benign lesions is not encouraged in the Netherlands, some patients insist on excision of the lesion. By including both benign as high-risk lesions, a realistic reflection of daily practice is given in this study. Even when not all lesions are excised by means of VAE, the introduction of VAE still resulted in a significant reduction of hospital costs per patient. This reduction is explained by a large cost benefit of the VAE

Figure 2. Distribution of scores on the BCTOS-cs for patients managed by means of SE (green) and VAE (pink) cohort. The darkest colours represent a score of 1 "no difference between breasts" and the lightest colours represent a score of 4 "a large different between breasts".



procedure compared to SE. A previous study in which only procedural costs were compared found comparable results with double costs for SE compared to VAE treatment ($3101 versus $1348).[22] Another study using probabilistic sensitivity analysis also showed that in 90% of the time VAE would likely be the cost saving option when compared to SE.[42] By also comparing costs during work-up, therapy and follow-up including re-excisions and treatment of complications, this study demonstrates the real-world financial impact of implementing VAE. Logically, the median time from first to last healthcare activity was significantly longer in the before cohort compared to the after cohort. However, the largest proportion of costs are made within the first 8 months and even after correction for this variable, cost differences remained significant.

The tendency towards less invasive management for high-risk breast lesions by means of VAE might result in more subsequent SE due to the higher upstaging risk of these high-risk lesions as compared to benign lesions.[6,22,26–28] However, subgroup analysis showed that both the treatment of benign, as well as high-risk lesions was associated with decreased costs when VAE instead of SE was performed. Moreover, our prediction model shows that even if the re-excision rate would rise due to an increased use of VAE, it would still be beneficial to use VAE instead of SE. It should be mentioned that conservative treatment is not included in this prediction model while a proportion of the excised benign lesions could have been managed without excision. In these patients, conservative treatment was always discussed first and excision was only performed if patients insisted on it. Although VAE is beneficial over SE, it should not be used as a replacement for conservative treatment in unequivocal benign lesions.

Comparable to literature, most patients in this study were satisfied with the cosmetic outcome after VAE; 94% of patients reported an intermediate to good cosmetic outcome.[16,19,21] On the contrary, previous studies reported a dissatisfaction with cosmetic outcome when SE was performed for benign breast disease in 25–32% of patients compared to the 5% that was found in our study.[14,43] Thus, the failure to demonstrate a difference in cosmetic outcome seems mainly attributable to the unexpectedly good cosmetic outcome after SE; 95% of patients reporting an intermediate to good cosmetic outcome. Breast swelling was more often seen after VAE, possibly due to the formation of a hematoma after the procedure which is the most common complication after VAE.[9,12,13,44] Compression after the procedure could help to prevent the formation of a hematoma after VAE and possibly optimise cosmetic outcome in these patients.[45,46]

This study is strengthened by the fact that costs associated with the full patient pathway were included. Not only the costs are laid out in detail but also the cosmetic outcome is reviewed in the same retrospective cohort comparing VAE and SE. Additionally, not only VAE was compared to SE but also the before cohort was compared to the after cohort. This way, the direct benefit of VAE implementation in clinical practice is demonstrated, showing that VAE is also beneficial when used for only a

proportion of excisions without replacing all SE. The VAE device used in this study costs approximately € 15.000 and would thus be profitable when VAE would replace SE in only 10 patients. This study is limited by its retrospective design with impaired quality of routine registry (missing, underreporting, or faulty interpretation of data) and risk of selection bias. An attempt was made to minimise selection bias by searching for eligible patients using two different strategies (biopsies and diagnosis code). Only direct healthcare costs are included in this study, while indirect costs such as work resumption could impact the cost-effectiveness as well. The reason for SE instead of VAE was inconsistently reported in the patient records thus could not be included for further analysis. Also, not enough data were available for the weight of the specimen after resection through VAE and SE and could therefore not be included but might have been an interesting variable for cosmetic outcome. Only patient reported cosmetic outcome was included and thus no conclusions can be drawn on clinician reported outcome. Adding an objective tool for cosmetic evaluation, such as the BCCT.core, could possibly help identify those patients with relatively poor perceived cosmetic outcome to optimise patient care.[47–49]

CONCLUSIONS

This study shows that the implementation of VAE reduces hospital costs dramatically in the management of patients with benign and high-risk lesions. The costs of patients managed with SE were more than double the costs of patients managed with VAE. A cosmetic benefit of VAE over SE could not be demonstrated in this retrospective study. Prospective evaluation of cosmetic outcome and a complete cost-effectiveness analysis including indirect costs should be performed in future research among patients undergoing VAE as a minimally invasive treatment option for these non-malignant lesions.

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AUTHOR STATEMENT

All co-authors have contributed to the development of the manuscript, approved its content and its submission to the journal, and have authorised the corresponding author to represent all co-authors in pre-publication discussion with the journal. The authors guarantee that the manuscript, or one with substantially the same content, was not published previously and is not being considered for publication elsewhere. The manuscript contains original unpublished work.

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