Hospitalization costs of TAVI in one Belgian university hospital

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Objective Considering the sizeable cost of transcatheter aortic valve implantation (TAVI) and conflicting cost-effectiveness studies, it is useful to gain more insight into the cost structure of the TAVI hospitalization. This study provides such a cost analysis and starts to evaluate options to soften the hospitalization cost burden in order to make TAVI economically more feasible.

Methods Costs for TAVI hospitalization in the University Hospital of Antwerp were analysed uni- and bivariate. Graphical and numerical displays of the data are supplemented with the non-parametric Wilcoxon rank sum statistic and Spearman rank rho correlation.

Results Overall, 47 percent of the cost could be attributed to the implanted valve and 21 percent was accounted for by the room costs. Further, costs seemed highly insensitive to pre-existing patient characteristics. Only patients with pulmonary hypertension were characterized with systematically higher costs (Wilcoxon rank sum *P*-value of 0.049). Complications related to TAVI had a significant upward impact on the costs and there was also evidence for a learning effect on total costs.

Conclusions In general the analyses showed that only limited options remain for cost reduction of the TAVI hospitalization cost. The most promising option is the reduction of the valve price. Avoidance of complications is hard to achieve given the current state of the art although this would significantly reduce overall costs.

Keywords TAVI – hospitalization – Belgium – cost analysis.

INTRODUCTION

Transcatheter aortic valve implantation (TAVI) is currently considered the standard of care in extreme risk patients with severe symptomatic aortic stenosis and as an alternative to surgery in those considered high risk¹. Cost-utility analyses are scarce, however, and seem to contradict each other. While Watt et al.² as well as Reynolds et al.³ argue that TAVI can be considered in all inoperable patients, Neyt et al.⁴ only approve initial reimbursement for the subgroup of anatomically inoperable patients. Consistent with these conflicting analyses, also reimbursement varies strongly across countries. In countries where decisive actions have been taken,

reimbursement varies in magnitude as well as in the patient selection. In Belgium, since there is no reimbursement at all, most costs are covered by the involved hospitals. In November 2012 the National Institute for Health and Disability Insurance has decided to put a budget aside for 25-30 reimbursements per year, which is the estimated amount of anatomically inoperable patients⁵. Neighbouring countries France and Germany, however, have more extensive reimbursements and in the Netherlands the College of Health Insurance advises to reimburse TAVI for all inoperable patients⁶⁻⁸. As a result, the frequency of TAVI differs strongly across countries. For example in France, the number of TAVI procedures amounted to about 38 per million inhabitants in 2011. This is a sizeable amount but still less than half the number of procedures in Germany (about 89 per million inhabitants). In Belgium, in absence of reimbursement, 289 procedures were performed in 2011. This amounts to about 26 per million inhabitants, a figure similar to that in the Netherlands⁹. Given the conflicting cost-effectiveness analyses and the size of the TAVI cost, it is highly interesting to gain more

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insight in the composition and determinants of these costs. As argued by Neyt et al.⁴, the current costs per QALY are (much) too high to defend a reimbursement for TAVI in high-risk, operable patients. Nevertheless, this conclusion can be altered if TAVI costs become similar to those of aortic valve replacement (AVR).

This study performs an analysis of hospitalization costs in one Belgian university hospital. First, the composition of costs is studied and, secondly, the drivers of these costs are identified. Once these elements are known, different possibilities to soften the TAVI cost burden may be considered to improve the economic feasibility of the procedure. The question whether this softening should evolve through more careful patient selection, selection of hospitals that are allowed to perform the procedure, or through other channels, will then remain open for further discussion.

DATA AND METHODS

Cost data were retrospectively collected from all consecutive patients who underwent a TAVI in the Antwerp University Hospital from December 2007 until June 2011. Prospective collection of medical data was performed by the interventional cardiologist. The study was approved by the Ethics Committee and informed consent was obtained by the patients both for the procedure and the data collection. This TAVI centre exclusively uses the Medtronic CoreValve. Only extreme and high-risk patients with severe symptomatic aortic stenosis in which Medtronic CoreValve implantation was considered feasible by the local Heart Team were included in this single-centre evaluation.

Hospitalization costs were retrieved on the basis of invoices and patient characteristics from medical records.

Patient characteristics

In addition to demographic information, medical records contained information on the cardiac history of the patient, associated comorbidities, risk factors and severity of the cardiac disease.

Cost data

Invoices of all hospitalizations of TAVI patients, starting after 18 December 2007 and ending before 30 June 2011 were retrieved. The invoices contained detailed information on all medical and other interventions performed on the patient during hospitalization (at the nomenclature level) and the corresponding tariffs. Since the data covered different years, direct comparison of the cost data was impossible. Therefore tariffs for 2011 were attributed to all interventions.

Statistical analysis

Medical records and invoices were blinded and linked on the basis of the patient number. Analyses were done with STATA. Results are reported as means, standard deviations, medians and ranges for continuous variables and as frequencies and percentages for categorical variables. Bivariate relationships were examined with the use of the Wilcoxon rank sum test and the Spearman's rho. Non-parametric methods were required due to cost-outliers and low amounts of observations in the categories of some variables.

RESULTS

Complete data were retrieved from the TAVI registry of the University Hospital of Antwerp for 86 persons between 19 December 2007 and 27 June 2011. All interventions were always done by a single team of physicians (1 interventional cardiologist and 1 cardiac surgeon).

Patient characteristics

Baseline characteristics are summarized in table 1. Mean age of the patients was 82 years (median 84; range 59-92 years) and the majority of the patients were female. Seventy-two percent of patients were in NYHA class 3 and 4 and the mean log Euroscore equalled 25.6 (median 25.38; range 1.22-73.94). For the aortic valve area (AVA), values ranged between 0.3 and 0.93 with a median of 0.60. The mean gradient with median 44 ranged between 4 and 91 and for the left ventricular ejection fraction (LVEF) values were between 26 and 84 whereas the median equals 60. A sizeable share of patients had a cardiac history and suffered from significant comorbidities, as can be seen in table 1. Five patients received a subclavian replacement of the valve, all other patients were treated with the transfemoral approach. All TAVI procedures were performed with general anaesthesia.

Costs

First, the total cost of the hospital admission of TAVI was analysed. These costs include reimbursements and out-of-pocket costs of all medical and non-medical interventions during the TAVI hospitalization. Incidentally it can include costs not related to the TAVI-intervention, but performed during hospitalization. Given the difficulty to evaluate whether costs are related or not, all costs were included.

Not all patients qualified for a TAVI. Therefore, possible candidates first underwent a technical selection to determine the feasibility for TAVI. The cost of this selection was not comprised in the TAVI

Table 1 Patient characteristics

Variables	Frequency (%) mean (SD)*	n	Variables	Frequency (%) mean (SD)*	n
Demographic variables			Comorbidities		
Age (years)*	81.8 (6.6)	86	AA	1 (1.2%)	86
Gender (male)	32 (37%)	86	Atrial fibrillation	19 (22.1%)	86
Risk indicators			Angina	18 (20.9%)	86
NYHA III, IV	62 (73%)	85	CAD	42 (48.8%)	86
Log EuroSCORE*	25.6 (15.2)	86	Carotid disease	4 (4.7%)	86
Severity aortic valve stenosis			CHF	26 (30.2%)	86
AVA (cm ²)*	0.6 (0.1)	82	CM	7 (8.1%)	86
Mean grad (mmHg)*	45.2 (17.0)	78	COPD	14 (16.3%)	86
LVEF (%)*	59.4 (12.7)	79	Diabetes	21 (24.4%)	86
Patient history			Hyperlipidaemia	29 (33.7%)	86
Previous MI	10 (11.6%)	86	Hypertension	48 (55.8%)	86
Previous stroke/TIA	2 (2.3%)	86	Mediastinal radiation	6 (7.0%)	86
Previous pacemaker	2 (2.3%)	86	PHT	14 (16.3%)	86
Previous CABG	25 (29.1%)	86	Porcelain aorta	5 (5.8%)	86
Previous PCI	17 (19.8%)	86	PVD	9 (10.5%)	86
Previous valve surgery	4 (4.7%)	86	Renal failure	11 (12.8%)	86

* For continuous variables, mean and standard deviation is given. *n* refers to the number of non-missing observations. NYHA New York Heart Association, AVA: aortic valve area, LVEF: left ventricular ejection fraction, MI: myocardial infarction, TIA: transient ischaemic attack, CABG: coronary artery bypass graft, PCI: percutaneous coronary intervention, AA: aorta aneurysm, CAD: coronary artery disease, CHF: congestive heart failure, CM: cardiomyopathy, COPD: chronic obstructive pulmonary disease, PHT: pulmonary hypertension, PVD: peripheral vascular disease.

hospitalization cost, because it was done in a separate hospitalization before the patients were admitted for TAVI. Follow-up costs were not considered either. Since outpatient costs were not available and there was only one patient with a readmission after the TAVI hospitalization, we had no possibility to provide information on the follow-up.

TAVI hospitalization costs amounted on average to €38,739 (SD €8,556) with median costs somewhat

smaller (€37,399). Total costs were slightly right-skewed (figure 1) and most observations were centred closely around €38,000. Three outliers with excessive costs could be identified.

Table 2 breaks down overall costs into 9 separate cost categories to gain further insight in the composition of costs related to TAVI hospitalization. The single largest cost category with a mean of €18,083 comprises only the valve cost. Eighty-one patients received one valve (€17,090), and five patients received two valves

Fig. 1 Boxplot of total costs.**Table 2** A breakdown in cost categories

Variable	n	Mean	SD	Min	Max	% total
Aortic valve	86	18,083	4,023	17,090	34,179	47
Pharmacy	86	816	618	335	4,555	2
Diverse non-reimbursed	86	501	1,426	2	6,117	1
Clinical biology	86	884	383	189	3,135	2
Revalidation	86	675	362	0	2,480	2
Surgery and technical acts	86	4,976	1,040	3,022	9,870	13
Medical imaging	86	607	264	170	1,591	2
Implants	86	2,129	2,627	71	7,169	5
Room costs	86	10,049	4,567	1,187	29,684	26
Total	86	38,739	8,556	28,210	73,791	100

after a malpositioned first valve (see later). The second largest cost category were room costs. Room costs relate to the standard nursing care and the so-called hotel costs and were remunerated with a fixed price of €594 per day. The high variation in room costs was caused by large differences in length of hospital stay which varied between 2 and 49 days. Furthermore, the categories 'surgery and technical acts', 'diverse non-reimbursed' and 'implants' showed a considerable amount of variation. The main cost components of

technical medical services were anaesthesia, the delivery catheter for the valve implantation and post-dilatation balloon catheters. The 'implants' category mainly consists of the cost for the pacemaker. However, also several smaller costs, like dilatation material for the lower limbs and implants for the percutaneous closure of the arterial access, are included. 'Pharmacy' comprises all medications during the hospitalization and several other, mostly small, products (e.g. stockings).

Table 3 Bivariate analysis between patient characteristics and overall costs

Variable	Z-statistic/ Spearman rho	P-value	Mean rank Total costs N0	Mean rank Total costs N1
Demographic variables				
Age	0.102	0.232	–	–
Gender	0.402	0.688	44.91	42.67
Risk indicators				
NYHA III,IV	– 0.801	0.423	39.48	44.31
Log Euroscore *	0.135	0.113	–	–
Severity aortic valve stenosis				
AVA (cm ²) *	0.015	0.864	–	–
Mean grad (mmHg) *	0.077	0.366	–	–
LVEF (%) *	0.048	0.575	–	–
Patient history				
Previous MI	– 1.145	0.252	42.38	52.00
Previous stroke/TIA	– 0.430	0.667	43.32	51.00
Previous pacemaker	1.862	0.063	44.27	11.00
Previous CABG	0.071	0.943	43.62	43.20
Previous valve surgery	– 0.267	0.790	43.34	46.75
Previous PCI	1.068	0.285	44.93	37.71
Comorbidities				
AA	1.631	0.103	43.98	3.00
Atrial fibrillation	– 0.265	0.791	43.12	44.84
Angina	0.817	0.414	44.63	39.22
CAD	1.806	0.071	48.25	38.52
Carotid disease	– 0.882	0.378	42.98	54.25
COPD	0.561	0.574	44.17	40.07
CHF	– 0.320	0.749	42.93	44.81
CM	– 1.208	0.227	42.53	54.43
Diabetes	– 0.357	0.721	42.95	45.19
Hyperlipidaemia	2.480	0.013	48.26	34.14
Hypertension	0.304	0.761	44.42	42.77
Mediastinal radiation	0.186	0.852	43.64	41.67
PHT	– 1.965	0.049	41.17	55.50
Porcelain aorta	– 0.175	0.861	43.38	45.40
PVD	– 1.065	0.287	42.52	51.89
Renal failure	0.407	0.684	43.92	40.64

* For continuous variables, Spearman rho is given. N0 stands for the group without the characteristic, N1 stands for the group with the characteristic. NYHA: New York Heart Association, AVA: aortic valve area, LVEF: left ventricular ejection fraction, MI: myocardial infarction, TIA: transient ischaemic attack, CABG: coronary artery bypass graft, PCI: percutaneous coronary intervention.

Contributors to the hospitalization cost

The following subsections deal with the factors associated with high hospital costs.

Baseline patient characteristics

After analysing the overall costs, we aimed to analyse if *a priori* patient characteristics were associated with these costs. Table 3 shows that this proved true for only a few characteristics. Relevant and statistically significant association with overall costs was mainly found for pre-existing pulmonary hypertension. Higher costs for patients with pulmonary hypertension were primarily related to implants (€3,297 vs €1,902) and room costs (€12,571 vs €9,558).

Cost of complications

Several unavoidable and costly complications came along with the TAVI procedure. However, not all patients need these medical acts, explaining a sensible amount of the variation in overall costs. The following three elements are discussed because of the significant size of the cost.

First, a permanent pacemaker implantation was regularly required after the TAVI procedure. The incidence of this pacemaker implantation is known to be higher for the CoreValve prosthesis compared to the Sapien prosthesis¹⁰. The cost of the implant of the device varied around €5,000. In our patient population, a subsample of thirty persons received the implant, explaining

the variation in the 'Implants' category. The incidence of the implantation of pacemakers in approximately one third (35%) of the cases corresponds to the findings from the UK CoreValve collaborative¹¹.

Another costly complication was the need for the implant of a second valve. In our sample five patients needed a second valve implant. This event shifted costs for the aorta valve from $\pm$ €17,000 to $\pm$ €34,000 and therefore patients with two valves had significantly larger costs compared to other patients.

A third complication was suboptimal vascular closure. The cost for this medical act involves the fee for the procedure and the cost for the materials used. Five patients needed this intervention and, depending on whether a stent was placed or not, the cost varied between €1,070 and €2,036.

Simultaneous diseases

Older patients often need more in-hospital medical care due to co-morbidity. The most costly example in the sample are two patients who needed haemodialysis treatment (€315 per dialysis) during their hospitalization. With 10 and 12 dialyses, respectively, the total cost amounted to €3,150 and €3,780.

Learning curve

Figure 2 shows all observations with a fitted regression line. The patient number is regressed against the overall hospitalization cost. A moderate learning effect can be fitted to the sample. The *P*-value for the regression

Fig. 2 Learning curve.

line is 0.068. The cost decrease over time is clearly caused by a narrowing variation.

TAVI approach

There are two ways of access to the heart to perform TAVI: subclavian and transfemoral. The outcome and cost of the procedure might therefore also be related to the approach of the procedure. The Wilcoxon rank sum test ($P=0.32$) shows that this was not the case in this sample.

In-hospital deaths

In our sample, 7 out of 86 patients died in the hospital. Costs for these patients were significantly higher (Wilcoxon rank sum P -value = 0.0457). The average cost per patient was €44,099 for this subgroup, while costs for other patients were €38,264 on average. The difference is caused by a high number of valve-in-valve implantations in these patients. On a total of five patients who underwent valve-in-valve implantation, three died in the hospital.

COST REDUCTIONS

This section briefly discusses several scenarios for conceivable savings. First, costs are closely related to the duration of the hospitalization. Even if no medications or treatments are received, staying in hospital for one day costs €620 (fixed *per diem* charges for hotel and nursing costs, pharmacy and clinical biology). Hence, we calculated the cost for patients in the three days before the discharge. Excluding in-hospital deaths, these costs amounted on average to €745 for the last day, €728 for the one but last day and €748 for the third day before discharge. The fact that average costs in the last days before discharge are not too far beyond the minimal amount of €620 could indicate that there might be at least some scope for a shorter length of stay.

It is likely that the incidence of pacemaker implantation will decrease and that valve prices will fall over time. A decline in the incidence of pacemaker implantations to e.g. 30 ($\pm 26/86$ patients) or 25 ($\pm 22/86$ patients) percent of the patients decreases average costs with €238 and €476, respectively. A fall in valve prices to e.g. €12,000, would decrease average costs with €5,385.

For TAVI to become cost effective in high-risk operable patients, costs for both procedures need to become similar because of very small differences in mortality. Also improvements in quality of life would make it worthwhile to implement TAVI, yet no evidence on this is available in the literature^{3,4,7}. With costs for surgical

aortic valve replacement estimated at €23,341 there is obviously still a long way to go⁷. Developments in valve prices, length of stay, learning effects and pacemaker incidence already lowered the current procedural costs for inoperable patients. Cost effectiveness should then be revised once costs equalize between procedures and/or when mortality and quality of life outcomes improve for high-risk operable patients.

DISCUSSION

This retrospective study provides real life cost data on 86 patients with TAVI in clinical practice for the period 2007-2011. To our knowledge this is one of the first studies to analyse the composition and drivers of the index hospitalization of TAVI.

For the University hospital of Antwerp, in prices of 2011, we calculated an overall average cost of the TAVI index hospitalization of €38,739. This finding corresponds to evidence found in the literature. It is highly similar to the calculation of the Belgian Health Care Knowledge Centre⁷ (€40,917), and it is comparable to numbers for Italy in Bartoli et al.¹² (€33,977) where costs are calculated from the hospital perspective. The difference with KCE is mainly due to a difference in the cost of the valve (KCE estimates it at €18,000 while this paper includes a cost of €17,090). The cost-effectiveness study related to the PARTNER trial for inoperable patients reports a hospitalization cost of approximately €58,800 (\$78,000)³.

Forty-seven per cent of the overall hospitalization cost was generated by the cost for the valve device. The charge for one valve in this study amounted to €17,090. The device cost is several times higher than the traditional aortic tissue valves (with prices in the US ranging from \$5,000 to \$6,500)¹³. A reduction of the valve prices would greatly improve the economic feasibility of the intervention.

Patients with pulmonary hypertension have higher costs. Implantation of a permanent pacemaker, valve-in-valve implantation and the placement of a covered iliac stent in case of suboptimal vascular closure, increased costs as well. Given the current state of the art, avoidance of these complications is not plausible, but it is clear that this is an area which deserves further attention. It will be of great benefit to the patient and will also reduce costs.

Further, costs decreased somewhat over the years. Since all interventions were performed by a single heart team, this could be an indication of a learning effect in addition to improvements in the device itself. Alli et al. have already demonstrated that radiation and fluoroscopy exposure decrease as physicians become more

experienced¹⁴. Gurvitch et al. found that TAVI outcomes improve with experience and device development¹³. These improvements over time seem to be translated in cost reductions as well.

STUDY LIMITATIONS

This study relates only to a limited number of patients treated in a single centre by a single physician. Obviously procedural practice and patient management might be different between hospitals. The exclusive use of the CoreValve device makes comparison with the Sapien device impossible and there is no possibility to compare the transfemoral with the transapical approach. The cost difference between the transapical and transfemoral approach is calculated to lie around €9,000⁶. Furthermore, pre-procedural evaluation and post-procedure follow-up costs were not considered in this paper.

At 26%, room costs were the second most important component of the total costs. Room costs refer to the *per diem* price for hotel and nursing services of a patient. For the University Hospital of Antwerp the price amounted to €593.67. This is much higher than the average in Belgium (€388 in 2010)¹⁵ and related to the high volume referral and teaching status of the hospital. In addition, costs included in the hospitalization are not necessarily restricted to costs of TAVI. In an old patient sample, unrelated comorbidity might cause supplementary in-hospital costs. In this sense, the calculated costs of TAVI are somewhat overestimated.

CONCLUSION

The overall average cost of the TAVI index hospitalization was €38,739. Device costs and room costs constituted 47% and 26% of these costs, respectively. Length of stay was an important driver of costs. Only very few significant associations could be found with the TAVI cost. A significant and relevant effect on costs was found for patients with pulmonary hypertension (higher costs). There is evidence of a learning effect: costs decrease somewhat over the years. On the basis of these results we conclude that only very limited options exist to soften the TAVI cost burden. Avoidance of complications and a reduction of device costs seem the most promising.

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CONFLICT OF INTEREST

Diana De Graeve received consultancy honoraria from Medtronic during the preparation of this paper. Johan Bosmans is part-time clinical proctor for Medtronic CoreValve.

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