Factors predicting the cost of endovascular management of intracranial aneurysms

Facteurs prédictifs du coût de la prise en charge endovasculaire de l'anévrisme intracrânien

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Abstract

Introduction: The management of intracranial aneurysms has evolved in the recent years, and endovascular coiling has become the first treatment option in many countries. In Tunisia, this neuroendovascular treatment meets a progressive but slow development, slowed down, by the economic component.
Aim: This study aimed to evaluate the global cost of endovascular treatment of cerebral aneurysms and determine the factors influencing the variation of direct medical cost.
Methods: A prospective study including patients who underwent interventional neuroradiology procedures for intracranial aneurysms between March 2019 and June 2019. Total cost (direct medical and non medical cost) was assessed using the micro-costing method. Statistical analysis (descriptive followed by a multivariate analysis) was performed by PSPP software with a p-value< 0.05 considered statistically significant.
Results: Twenty-nine patients were included (mean age 54±14 years). The average overall cost of treatment was 15 877 DT (5 081€), ranging from 8 005 DT (2 562 €) to 36 325 DT (11 624 €). The average cost of medical devices used during the procedure was 13 548 DT (4 335 €) which represents 85.3% of the total cost. The direct medical cost was particularly influenced by aneurysm's and neck's size, and by the total cost of coils.
Conclusions: The medical devices used during the procedure greatly influenced the direct medical cost of the management of intracranial aneurysms.

Key words: Interventional neuroradiology. Cost-analysis. Coiling. Aneurysm embolization

Résumé

Introduction: La prise en charge des anévrismes intracrâniens a évolué au cours des dernières années. Le coiling endovasculaire est devenu le traitement de première intention dans de nombreux pays. En Tunisie, cette technique rencontre un développement progressif mais lent, freiné, principalement, par la composante économique.
Objectif: Evaluer le coût global du traitement endovasculaire des anévrismes cérébraux et de déterminer les facteurs influençant la variation du coût direct médical
Méthodes: Une étude prospective incluant les patients ayant subi des procédures de neuroradiologie interventionnelle pour des anévrismes intracrâniens de mars à juin 2019. Le coût total (coût direct médical et non médical) a été évalué en utilisant la méthode du micro-costing. Les analyses statistiques (descriptive suivie d'une analyse multivariée) ont été effectuées à l'aide du logiciel PSPP®. Une valeur p<0,05 a été considérée comme statistiquement significative
Résultats: Vingt-neuf patients ont été inclus, d'âge moyen 54±14 ans. Le coût global moyen de la prise en charge était de 15877DT (5081€), variant de 8005DT (2562€) à 36325DT (11624€). Le coût moyen des dispositifs médicaux utilisés pendant la procédure était de 13548 DT (4335€) ce qui représente 85,3% du coût total. Le coût direct médical était particulièrement influencé par la taille de l'anévrisme et celle du collet et par le coût des coils.
Conclusion: Les dispositifs médicaux utilisés au cours de l'acte ont grandement influencé le coût direct médical de prise en charge des anévrismes intracrâniens par voie endovasculaire.

Mots clés: Neuroradiologie interventionnelle, Analyse de coût, Embolisation d'anévrismes

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INTRODUCTION

Intracranial aneurysm (IA) represents a cerebrovascular disorder described by an abnormal dilation of the arterial wall of brain vessels. It was reported that IA has high mortality and morbidity in patients between 40 and 60 years old and that 1% to 5% of the general population worldwide has been affect by this disease (1,2). Neurosurgical clipping of the malformation and neuroradiology treatment (endovascular coiling) are two accepted options for treating cerebral aneurysm. However, since the 2000s, endovascular treatment has shown many advantages, notably for the elderly, faster recovery, shorter hospitalization, less pain, and fewer complications in the postoperative period when compared to surgical clipping (3). Therefore, the management of AI has changed, and endovascular coiling has become the first treatment option in many countries (3–5). In Tunisia, this procedure meets a progressive but slow development, slowed down, mainly, by the economic component.

Activity based payment was introduced in 2006 after negotiation between the parties directly concerned. Therefore, a lump sum is assigned by the National Health Insurance Fund to the revenue generated for our hospital. This amount is assumed to reflect the costs of hospitalization and medical devices MD) used for this intervention. The cost of the intervention that exceeds this lump sum will be reimbursed later. Unfortunately, this repayment is usually delayed for up to 7 years. Resulting in a significant gap between expenditures and revenues not allowing hospitals to reach financial balance. Furthermore, the fee paid by the Health Insurance is only 7000 DT (2093 €) and with the increasing costs of medical devices, this package is no longer sufficient for flat rate billing. Such research can be used to reassess the lump sum repaid by health insurance.

This study aimed to evaluate the global cost (direct medical and non-medical cost) of endovascular treatment of cerebral aneurysms and to determine the factors influencing the variation of the direct medical cost in order to be considered when redefining the lump sum to be refunded by health care insurance.

METHODS

This prospective study focused on patients with aneurysms who underwent an interventional neuroradiology procedure at the Neuroradiology Department in the National Institute of Neurology Mongi-Ben Hamida between March 2019 and June 2019. Patients were followed from the day of the INR procedure to their discharge date. All patients who underwent an INR procedure for small, large, ruptured or unruptured aneurysms were included in this study. Data on pharmaceuticals and MD used during the procedure were collected by direct observation and from the neuroradiology department's traceability sheets, indicating the various drugs, non-implantable MD (guides, catheters, microcatheters, micro guides, angiography kit,) and implantable MD (coils and stents) used. Pharmaceuticals and devices used during hospitalization were collected from the 24-hour signs of the different care units.

Cost analysis

Direct costs estimates were based on direct medical costs and direct non-medical costs. Concerning direct costs, they included medications, MD, diagnostic tests, physician consultation fees, and hospitalization costs. However, direct non-medical costs included depreciation allowances, transportation, and unit expenses. Follow-up care after patients discharge could not be performed in our study; hence, intangible costs were not included. Economic data of different services were provided from the hospital billing system. The cost of medications reported in this article was collected using their purchase price from the central pharmacy in Tunisia for 2018 and 2019. However, the medical devices valuation was performed from the 2018 tender and 2019 consultations.

Statistical analysis

Statistical analysis (descriptive followed by a multivariate analysis) was performed by PSPP software with a p-value < 0.05 considered statistically significant. Qualitative variables were expressed as numbers and frequencies. The correlation between cost and other qualitative and quantitative parameters was established with the Spearman, Pearson, and Mann-Whitney tests. Afterwards predictive factors identified by a bivariate analysis were introduced in a linear regression model with the objective to determine the independent and predictive factors of direct medical cost.

RESULTS

Twenty-nine patients underwent endovascular treatment for ruptured or unruptured aneurysms. The sex ratio was M/F = 0.81, and the mean age of patients was 54±14years. The median overall stay was five days (range 1–20). Five patients (17,2%) presented postoperative complications. A description of the clinical parameters of the patients is presented in Table 1.

Table 1. Clinical parameters of patients treated with aneurysm embolization

Patient characteristics	Number
Sex	
Male	13 (44.8%)
Female	16 (55.2%)
Age	
Median (min - max)	55 (17 - 80)
Total length of stay	
Median (min - max)	5 (1 - 20)
Comorbidities	
Arterial hypertension	11 (37.9%)
Tabaco	5 (17.2%)
Diabetes	1 (3.4%)
Aneurysm qualification	
Ruptured	25 (86.2%)
Unruptured	4 (13.8%)
Aneurysm size	
0 - 5 mm	14 (48.3%)
6 - 10 mm	11 (37.9%)
11 - 15 mm	4 (13.8%)
Aneurysm neck size	
Small	25 (82.8%)
Large	4 (17.2%)
Location	
Anterior communicating	13 (44,8%)
Carotid	8 (27.6%)
Vertebral-basilar artery	3 (10.3%)
Other locations	5 (17.2%)
Complications	5 (17.2%)

The overall mean cost of treatment was 15 877 DT (5 081€), varying from 8 005 DT (2 562 €) to 36 325 DT (11 624 €).The mean direct medical and direct non-medical costs were 14 588DT (4 668€) and 1 290DT (413€). Pharmaceuticals and medical equipment accounted for the

most significant percentage of the total costs (88,2%) (of which 85,3% for the medical devices).The mean cost of medical devices used during the procedure was 13548 DT (4335€),varying from6 152 DT (1 969€) to 33 982 DT (10 874 €).INR procedure–associated costs are presented in Table 2.

Table 2. Distribution of the different costs in relation to the average total cost.

	Mean (DT)	Minimum (DT)	Maximum (DT)	Percentage
Drugs	460	216	1 940	2,9 %
Medical devices	13 548	6 152	33 982	85,3 %
Laboratory	81,440	44.5	474	0,5 %
Radiology	111	30	435	0,8 %
Hospital stays	230	40	1 200	1,7 %
Direct non-medical costs	1 300	1 250	1 550	8,2 %
Total mean cost	15 877	-	-	-

We were also interested in separating the costs of pharmaceuticals between those used during the intervention and those used during hospitalization. Results indicated thatmedications and MD used during the intervention were 12 061 DT (3 860€) (94.8% of direct medical costs) while those used during hospitalization were insignificant (0.86%of direct medical costs). In contrast, for patients who received embolization without remodeling technique, the mean costs of coils alone were 9 351DT (2992 €). For patients who received embolization with remodeling technique, the cost of coils associated with balloons was 9500 DT (3 040 €) .Table 3 represent the distribution of the costs of medical devices used during aneurysm embolization with and without the remodeling technique.

Table 3. Costs of medical devices used during aneurysm embolization without Remodeling technique

Number of aneurysm embolization without remodeling technique		22	
Designation	**Average cost**(DT)	**% Of average cost of MD**	**% Of average overall cost**
Coils	9 351	69.5%	59.2%
Micro guides	1 245	9.3%	7.9%
Microcatheters	1 468	10.9%	9.3%
Carrier catheters	797	5.9%	5%
Others *	581	4.3%	3.7%
Average cost of MD	13 452	99.9%	-
Average total cost	15800	-	85.1%
Number of aneurysm embolization with remodeling technique		**7**	
Coils	6 501	46,9%	40,3%
Balloon	2 993	21,6%	18,6%
Micro guides	1 246	9%	7,8%
Microcatheters	1 746	12,6%	10,8%
Carrier catheters	797	5,8%	4,9%
Others *	565	4%	3,5%
Average cost of MD	13 850	99,9%	-
Average total cost	16 118	-	85,9%

*The medical devices used during the intervention such as guides, hemostatic valves, injection syringes, sterile fields …

Furthermore, in table 4, we mentioned the determinants of the direct medical cost, and we reported that it was not influenced by the total length of stay or the hospitalization in the intensive care unit. Indeed, the correlation test was statistically significant between the cost of pharmaceuticals and the number of coils and other medical devices used during the procedure. It was also significant between the cost of pharmaceuticals (medical devices) and the size of the aneurysm and the size of the neck.

Table 4. Results of statistical tests performed on factors affecting the variation of the direct medical cost during the procedure

Factors	Statistical test	p	Correlation coefficient
Total cost of medical devices	Spearman's Rho	< 0,001	0,99
Total cost of drugs	Spearman's Rho	0,02	0,47
Total cost of coils	Spearman's Rho	< 0,001	0,80
Total cost of microcatheters	Pearson	< 0,001	0,84
Cardiovascular risk factors	Mann-Whitney	0,12	-
Length of stay	Spearman's Rho	0,14	-
Stay in intensive care unit	Spearman's Rho	0,12	-
Aneurysm's qualification (ruptures or unruptured)	Mann-Whitney	0,81	-
Aneurysm's size	Spearman's Rho	0,021	0,43
Aneurysm's neck size	Spearman's Rho	0,048	0,47

Table 5 showed that total cost of coils, total cost of microcatheters and total cost of drugs were independent and predictive factors of direct medical cost.

Table 5. Independent and predictive factors affecting direct medical cost: Linear regression

Factors	β	% 95 CI*	p
Total cost of coils	0,954	[0,887 - 1,042]	< 0,0001
Total cost of drugs	2,164	[0,655 - 3,673]	0,007
Total cost of microcatheters	2,656	[1,221 - 4,099]	0,001

* CI: confidence interval R2 = 0,955 p < 0,0001

DISCUSSION

Our study is considered the first economic evaluation of intracranial aneurysm treatments using embolization in Tunisia. This sample is the only sample that has been published and that includes all expenses related to patients care. In our study, the median length of stay was five days with a maximum of 20 days (due to prolonged hospitalization) and a minimum of 24 hours (for post embolization monitoring). Similarly, the Moroccan study by Cheikh et al. reported a median length of stay of seven days, one day in the intensive care unit and five days in the medical units, with a minimum of four days and a maximum of 11 days (6). Generally, the overall stay in hospital is considered acceptable allowing our institution to avoid nosocomial infections and to admit more patients. However, in our series, complications occurred in 17.2% (n=5) of patients treated by embolization for aneurysms, with the majority not related to the endovascular procedure but rather to postoperative hospitalization (ischemic stroke after aneurysm occlusion, subarachnoid hemorrhage from aneurysm rupture, and cardiorespiratory arrest). In a Pakistani study ischemic stroke and aneurysmal rupture were the most two frequent complications reported (7). Our series concluded that the overall average cost of an endovascular procedure on an intracranial aneurysm was 15 877 DT (5 081 €) per patient. In contrast, the average cost of endovascular treatment in France was estimated by the retrospective study of Labalette et al. to be 16 356 € (52 339 DT) (8).

There are some possible explanations for the difference in the average overall cost between the two studies. In fact, in Labalette et al. study patients treated for ruptured aneurysm are hospitalized in the intensive care unit (ICU) even if they do not meet all the eligibility criteria. Consequently, the hospitalization costs are high (the cost of patients' ICU visits accounted for 56.8% of total costs). In Morocco, Cheikh et al. reported an average cost amounting to 7 528€ (24 089 DT), with extremes ranging from 4 784 € (15 309 0DT) to 32 172 € (102 950 DT) (6). In fact, we concluded that the cost of pharmaceuticals and medical equipment occupied the major part of the total cost

(88.2%), specifically stents, coils, micro-catheters, balloons, and guides regardless of the technique used (with or without remodeling), showing that the high cost of medical devices is one of the major handicaps of the development of this activity. Indeed, the correlation was statistically significant between the cost of medical devices used (coils and micro-catheters) and the direct medical costs (p<0.001). Labalette et al. concluded that the average cost of the MD used was 5 226€ (16 723 DT) for ruptured aneurysms and 7 746€ (24 787 DT) for unruptured ones, with 55.7% represented by the cost of coils (8). Another study conducted by Zubair Tahir et al. determined the cost of MD, which amounted to 2 712 € (8678.4 DT), representing 59.2% of the total average hospitalization cost (7). A previous American study carried out at the University of Utah, by Twitchell and al. the cost of pharmaceuticals used during the embolization procedure represented 50.8% of the total cost, including 43.2% for MD (9). In fact, major part of medical devices is not made in Tunisia and there is no pricing regulation of MD by the ministry of health. Therefore, suppliers offer free choice of prices. These results were also consistent by Cheikh et al study (6). Several studies have been interested in evaluating the cost effectiveness of endovascular coiling versus surgical clipping of ruptured or unruptured intracranial aneurysms and comparing clinical outcomes. In this context, Ballet and al presented in a retrospective study from France that although the endovascular procedure tended to be more expensive in terms of sterile single-use medical devices (coils, microcatheters), this increase was more than compensated by savings in personnel costs and the duration cost of hospitalization (10). Although, both surgical and endovascular techniques remain indispensable for the treatment of aneurysms, the endovascular technique has many advantages (3). However, the limited lump sum repaid by health insurance funds does not encourage healthcare professionals to use this technology as much as possible. As matter of fact, the procedure generally has lengthy repayment terms. This imposes a significant burden and impact heavily on the hospital budget. Since, the national health insurance aims to facilitate patient access to a quality care with a minimal contribution, they must be interested and encourage the endovascular management of IA by improving the fees allocated for this technique. The reassessment of the lump sum amount of this interventional neuroradiology and the decision to reimburse new embolization items such as hydrocoils should also have a positive financial impact on the embolization activity in our institution. In this study, we were also interested in identifying the determinants of the total cost of endovascular treatment of aneurysms. In fact, results showed that the direct medical cost was influenced by neither the total length of stay (p=0.14) nor hospitalization in the intensive care unit (p=0.12). Nevertheless, it was a statistically significant with aneurysm size (p=0.021) and neck size (p=0.048), respectively. These findings can be explained by the low cost of the pharmaceutical products used during hospitalization and the low cost of the hospital stay itself. Previously published studies reported the same results as ours and showed that there was no correlation between the total length of hospital stay or only the intensive care stay and the overall cost (p=0.096) and (p=0.073) (6). However, in a Canadian study by Bekelis and al. aimed to develop and validate a predictive model of the cost of hospitalization after coiling a cerebral aneurysm. showed the impact of hospital stay on the overall cost of care with a value of p<0.0001 (11). Another French study has shown the importance of the cost of the hospital stay on the overall burden and accounted for 42% of the overall cost (6 908€ (22 105 DT) for 16 356€ (52 339 DT)) (8). These differences can be explained by the difficulty to transpose our economic estimates to the medical and economic work of studies carried out in other countries, given the differences in the medical care system. In our study, we also found three independent and predictive factors of direct medical cost: total cost of coils, total cost of microcatheters and total cost of drugs. On the other hand, in the study by Twitchell and al, the authors found independent and predictive factors different from ours. This is probably due to the difference on sample size: 29 in our series and 469 in Twitchell's series (9).

Finally, this study allowed us to evaluate the real cost of an embolization procedure, but there were several limitations associated with this review. Firstly, the small size of this cohort. Secondly, the follow-up and monitoring of the patient after their discharge was not evaluated. Finally, other aspects of indirect costs, such as meals out of the house, parking, and childcare costs could not be included in our study.

CONCLUSION

The pharmacoeconomic study provides a unique tool to evaluate health outcomes in monetary terms and inform health care decisions. Our study is a pharmacoeconomic evaluation of interventional neuroradiology procedures on aneurysms. It has highlighted that the higher price of the endovascular procedure was most frequently associated with the cost of medical devices. Comparing to the surgical technique, this increase is largely balanced by the savings made on the occurrence of complications and the duration and cost of hospitalization. Given the numerous advantages of endovascular treatment and the evolution of medical device technology, health authorities must encourage the neuroradiological management of AI. This can be achieved after reviewing the packages allocated by the National healthcare funds in order to limit the financial burden of this technique.

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