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# Economic evaluation in the treatment of unruptured intracranial aneurysms in the Swiss healthcare system: a retrospective cost evaluation

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## Summary

The choice of modality of treatment for unruptured intracranial aneurysms is based on various clinical aspects and the patient's preference. Financial considerations should not be among these. To evaluate any financial variations between endovascular and microsurgical treatment of unruptured intracranial aneurysms in the Swiss healthcare system, we retrospectively reviewed 100 consecutive aneurysm cases treated as inpatients in our institution.

Case-based financial data were collected (revenues, costs, net earnings) and compared between the treatments.

Among 100 consecutive aneurysm cases treated at our institution (2021–2023), 58 were unruptured intracranial aneurysm. Treatment was endovascular in 33, microsurgery in 23 and conservative/antibiotic in 2 cases. Length of stay (but not duration in the intensive care unit) was longer after microsurgical treatment. Total median revenues (public insurance, private insurance, material reimbursement) were Swiss Francs (CHF) 30,012.25 with a maximum of CHF 125,337.20 and a minimum of CHF 9543.25. No marked difference was found between the treatment groups (endovascular and microsurgery). Despite the fact that median net earnings per patient were positive (CHF 3655.03), more than one third of all cases led to a net loss for the hospital with a tendency for more stable net earnings in microsurgery cases. The only factor associated with a higher risk of net loss per case was higher implant costs in endovascular cases.

Reimbursement within the Swiss healthcare system does not promote financial bias for decision-making in treatment modality for unruptured intracranial aneurysm. The fact that one third of all cases does not result in positive net earnings (even in the highly paid unruptured intracranial aneurysm sector), although overall net earnings were positive, should be monitored – especially in times of rising costs.

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## Introduction

Decision-making for the modality of treatment of unruptured intracranial aneurysms may be based on various aspects. Medical arguments, usually foremost, comprise the durability of the treatment; the configuration, size and location of the unruptured intracranial aneurysm; comorbidities; treatment complexity; invasiveness; need for antiaggregation or invasive follow-up diagnostics, etc. Even though counselling should primarily be based on medical factors, non-medical considerations might also play a role in deciding whether endovascular or microsurgical treatment of an unruptured intracranial aneurysm is recommended. These may include personal preferences or beliefs (held by the treating professional or the patient) or financial considerations [1–4].

In 2015, Swiss healthcare costs had risen to 11.7% of Gross Domestic Product (GDP) [5], the second highest in Europe. According to 2013 Organisation for Economic Co-operation and Development (OECD) statistics, annual healthcare expenditure per capita exceeded US$ 5500 and was ranked second highest among 27 countries evaluated [6]. According to the same data, the density of nurses and psychiatrists in Switzerland is the highest among OECD countries, while the number of physicians per capita is among the highest. Thus, the Swiss healthcare system can be considered excellent although expensive [7].

In common with many other healthcare systems worldwide, reimbursement for in-hospital treatments in the Swiss healthcare system is based on diagnosis-related groups (DRGs). The final amount reimbursed for a treatment is therefore dependent on various factors, such as the primary diagnosis, secondary illnesses or pre-conditions, complications throughout the stay and the method of treatment. In Switzerland, the method of treatment is based on the Swiss (CH) Operation Classification (CHOP), which was derived from the international statistical classification of diseases and related health problems (ICD). The reimbursement for a given disease may vary as it depends on the particular treatment method / CHOP code used. Usually, operative CHOP codes contribute to higher reimbursements than non-operative codes (www.bfs.admin.ch or www.swissdrg.org).

As in most European healthcare facilities, financial controlling in Swiss hospitals is carried out by economists or accountants, who regularly update the leading physicians on relevant numbers including Earnings Before Interest, Taxes, Depreciation and Amortisation (EBITDA) and the corresponding margin.

Whenever monetary considerations play into medical decision-making, risks of bias arise.

To closely monitor eventual monetary bias risks for medical decision-making and to detect potential risk factors for negative net earnings, we evaluated the treatment of unruptured intracranial aneurysm in particular as it is, on the one hand, a high-volume business (in terms of costs and earnings) and, on the other hand, a highly discussed medical decision process.

## Methods

We reviewed the treatment costs of 100 consecutive cases with intracranial aneurysms admitted for inpatient treatment at our hospital within the past two years (23 February 2021 – 30 March 2023), of which 58 were unruptured.

*Rationale of local multidisciplinary decision-making at our institution:* Our hospital is a tertiary care centre in central Switzerland within an area of coverage of approximately 800,000 people. We have a dedicated neurovascular decision and treatment team, on on-call and off-call duty, that consists of two neurosurgeons trained in neurovascular microsurgery and three interventional neuroradiologists trained in endovascular procedures. All microsurgical and endovascular techniques for the treatment of unruptured intracranial aneurysm are thus offered at our institution.

All elective procedures are routinely processed within a weekly neurovascular board. Treatment recommendations are mutually made and brought to the patients, mainly taking into account standard considerations like patient characteristics (age, comorbidities, medication, preferences), aneurysm characteristics (size, accessibility, aspect ratio, shape) and treatment characteristics (durability, need for additional devices/medication). Non-elective procedures, which require immediate action, are decided bilaterally (neurosurgery and interventional neuroradiology). Re-evaluation of these decisions is regularly done through post hoc discussion in the board.

Net earnings and revenues of the 58 cases of unruptured intracranial aneurysm treated in the corresponding time period were reviewed on an individual case basis; revenues were further divided into general revenue by public insurance, additional revenue by private insurance and implant revenue. Treatment costs per case were further divided into facility costs/interests/depreciation, general costs of treatment and direct case costs, the last item comprising implant costs. This definition – as set by our local controlling persons – divides everything that goes into one individual patient (e.g. implants, medication, etc; direct case costs) from costs that arise during treatment and can only be attributed by time or area used (e.g. cost of nursing staff, operating theatre time, physician costs, anaesthesia, room capacity, etc; general costs of treatment). The following patient and treatment characteristics were obtained from our patient information system (EPIC System Corporation, Verona, WI, USA): Unruptured intracranial aneurysm treatment (microsurgery, endovascular), discharge (home, rehabilitation, nursing care, death), duration of stay (days), number of intensive care unit (ICU) hours, complexity of care in ICU (Nine Equivalents of nursing Manpower Score or NEMS [8] and Simplified Acute Physiology Score or SAPS [9]).

Treatment decisions were completely independent of this evaluation.

Statistical analysis was done using Stata 18 (StatCorp LLC, Texas, USA). Data are not normally distributed. Values are given as median and interquartile ranges (Q1–Q3), whenever appropriate. For two-sample comparison, the Wilcoxon rank-sum test (Mann-Whitney) was applied. Currency is CHF (Swiss Francs).

Due to the retrospective nature of the study, a protocol was not prepared. Trial registration was not applicable.

## Results

Over the 105-week period, 100 cases of intracranial aneurysms received inpatient treatment at our institution, of which 58 were unruptured.

Of these 58 cases, 23 were treated microsurgically, 33 were treated endovascularly and 2 were treated conservatively (one received antibiotic treatment, the other anti-seizure medication). In 55 cases, only one aneurysm was treated at the time. In 3 cases (all microsurgery), 2 aneurysms were treated concurrently. Given that treatment decisions, as well as costs and revenues, were completely different in the two conservatively treated cases, these were not included in further analyses. Hence all analyses comprise 56 treated patients.

Patient characteristics showed a higher percentage of endovascular treatment in the posterior circulation, but otherwise did not differ markedly between microsurgically and endovascularly treated cases. Of the 56 patients, 48 were discharged home directly, while 6 went to rehabilitation before returning home (4 after microsurgery and 2 after endovascular therapy). One patient was discharged to a nursing home and another died in hospital, both after endovascular treatment (table 1).

Mean treatment characteristics of both groups are summarised in table 2. Patients stayed in hospital for a median (Q1–Q3) of 4 (2–7) days for their treatment. Length of stay was longer in microsurgery cases: 6 (4–8) vs 3 (2–5). Median duration of stay in the ICU was volatile, but without obvious differences between the two groups (combined: 20 [18–24]; microsurgery: 21 [19–25]; endovascular: 19 [18–23]). It is therefore noteworthy that the SAPS scores were higher in the endovascular cases, but the NEMS scores were higher in microsurgery cases (SAPS: approx. 25% difference; NEMS: approx. 50% difference, when comparing the medians) (table 2).

Median (Q1–Q3) total revenue per case was CHF 30,012.25 (24,235.05–40,563.28) with a maximum of CHF 125,337.20 and a minimum of CHF 9543.25. No marked difference was found between the treatment groups, with CHF 29,102.28 (22,206.52–42,702.28) for the microsurgery vs CHF 30,012.25 (25,468.02–38,246.25) for the endovascular cases, respectively (p = 0.94). Median (Q1–Q3) revenues by public insurances and additional revenues by private insurances were, respectively, CHF 23,859.71 (22,022.49–29,102.28) and CHF 0 (0–0); there were no visible differences for microsurgery vs endovascular cases, either for public insurances (CHF 29,102.2 [22,019.13–38,257.64] vs CHF 23,859.71 [22,728.76–27,307.42]; p = 0.41) or private insurances (CHF 0 [0–10,585.00] vs CHF 0 [0–0]; p = 0.14). Additional implant reimbursements were CHF 1435.06 (0–6152.54), being, as expected, almost exclusively attributable to endovascular cases: CHF 0 (0–0) and CHF 3204.14 (1793.83–6457.50) in microsurgery and endovascular cases, respectively; p = 0.00001.

Total costs were CHF 26,226.89 (23,058.24–33,251.15) and comparable between the groups: CHF 26,223.10 (19,559.13–33,838.19) and CHF 26,230.69 (23,565.75–30,161.02) for microsurgery and endovascular groups, respectively (p = 0.72).

Direct case costs were lower and less volatile in microsurgery cases: CHF 4261.22 (3586.20–4780.25) and CHF 16,653.82 (15,004.93–18,432.49) in microsurgery and endovascular cases, respectively; p = 0.0001. Implant costs were substantially higher in endovascular cases and contributed substantially to direct case costs: CHF 1052.79 (836.09–1372.98) and 13,212.33 (10,467.78–13,757.82) in microsurgery and endovascular cases, respectively; p = 0.0001. Conversely, general costs of treatment were substantially higher in microsurgery cases: CHF 19,866.94 (14,650.47–25,154.77) and CHF 8966.79 (7403.24–11,439.67) in microsurgery and endovascular cases, respectively; p = 0.0001. Facility costs/interest/depreciation did contribute to total costs, but were as low as CHF 2334.36 (1533.92–2773.44) and 1106.79 (745.37–1444.93) for microsurgery and endovascular cases, respectively (p = 0.001); as expected, they were higher in microsurgery cases due to longer duration of stay.

The most pronounced difference was thus seen in the weighting of direct case costs and general costs of treatment, which showed anticipated differences between the two groups, that, in the end, were balanced in the total costs.

Given higher median total revenues than total costs per case, median net earnings per case could be achieved and were as high as CHF 3655.03 (%1310.69–9267.88) with a tendency for a lower risk of net losses in microsurgery cases at CHF 5818.62 (−372.22–12,261.83) vs 1145.27 (−2851.13–6925.50) for endovascular cases, p = 0.08 (figure 1).

Nevertheless, far from all cases closed with positive net earnings. In fact, 19 of the 56 cases (33.9%) closed with a loss of money, due to higher costs than revenue; specifically, 13 of the 33 endovascular cases (39.4%) and 6 of the 23 microsurgery cases (26.1%) were not closed with positive net earnings (p = 0.23) (figure 2).

To determine which factors contributed to lower net earnings or even losses in certain cases, we looked at the relationship between net earnings and the variables total length of stay, hours in the ICU and implant costs. Neither a longer duration of stay nor more time in the ICU was correlated with negative net earnings (data not shown). The only factor that tended to cause higher risks of net losses was higher implant costs, which (as pointed out previously) were only of relevance in endovascular cases (figure 3).

## Discussion

The decision concerning the treatment modality for unruptured intracranial aneurysm in the Swiss healthcare system should obviously be made without bias related to monetary matters. Overall revenues, net earnings, rates of non-profitable cases did not display marked differences between the two treatment modalities (microsurgical clipping and endovascular treatment). Nevertheless, we found distinct differences in cost distribution – which were not unexpected. Direct case costs (everything that goes “into the patient”,

**Table 1:**
Patient characteristics (total case number of 56: 33 endovascular cases plus 23 microsurgical cases – 2 conservative cases were excluded from further analysis).

| | | Endovascular (n = 33) | Microsurgery (n = 23) |
|---|---|---|---|
| Age (years, mean±SD) | | 58±12 | 60±8 |
| Gender (f:m:d) | | 22:11:0 | 15:8:0 |
| Aneurysm location | Anterior | 25 (76%) | 22 (96%) |
| | Posterior | 8 (24%) | 1 (4%) |
| Discharge | Home | 29 (88%) | 19 (83%) |
| | Rehabilitation | 2 (6%) | 4 (17%) |
| | Nursing Care | 1 (3%) | 0 (0%) |
| | Death | 1 (3%) | 0 (0%) |

**Table 2:**
Treatment characteristics (total of 56 cases: 33 endovascular plus 23 microsurgical cases – 2 conservative cases were excluded from further analysis). Results indicated as median and interquartile range (Q1–Q3).

| | Total (n = 56) | Endovascular (n = 33) | Microsurgery (n = 23) |
|---|---|---|---|
| Length of stay (days) | 4 (2–7) | 3 (2–5) | 6 (4–8) |
| Time on ICU (hours) | 20 (18–24) | 19 (18–23) | 21 (19–25) |
| SAPS points | 20 (15–23) | 20 (17–25) | 16 (14–19) |
| NEMS points | 60 (42–78) | 48 (39–42) | 72 (63–78) |

ICU: intensive care unit; NEMS: Nine Equivalents of Nursing Manpower; SAPS: Simplified Acute Physiology Score.

e.g. implants, medication, …) were higher in endovascular cases, while general treatment costs (costs that are attributed to a certain case per time interval or per area used, e.g. medical staff, operating theatre minutes, ICU time, …) were higher in microsurgery cases. As total costs were comparable between the treatment groups, we consider this difference in cost distribution to be due to technical reasons and do not see any influence on the treatment decision.

Microsurgically treated patients had longer stays and thus higher facility usage costs. Yet, due to slightly higher revenues, the latter were equalised. This points to fair and realistic revenue policies as conducted by the Swiss health-

**Figure 1:** Graphical display of net earnings and revenues (left) and costs (right) per case, divided into microsurgery cases (blue) and endovascular cases (red). All revenues and costs showed high volatility. Median total revenues were higher than median total costs thus net earnings per case could be obtained (far left). Total revenues (2nd from left) are divided into revenues by public insurance (3rd from left) plus additional implant revenues (whenever feasible, 4th from left) plus additional revenues by private insurance (in 14 cases, 5th from left). The differences on the side of earnings were higher additional implant revenues in endovascular cases (p = 0.00001) and a tendency to higher additional revenues from private insurances in microsurgery cases (p = 0.14). Total costs (leftmost) derive from facility costs/interest depreciation (2nd from left), general costs of treatment (3rd from left) and direct case costs (4th from left). The latter comprise implant costs (far right column, separated). Higher facility costs/depreciation/interest were documented in microsurgery cases (p = 0.001), while higher implant costs arose in endovascular cases (p = 0.0001). All data given as median and interquartile ranges. Monetary values are displayed in CHF (Swiss Francs). EVT: endovascular treatment.

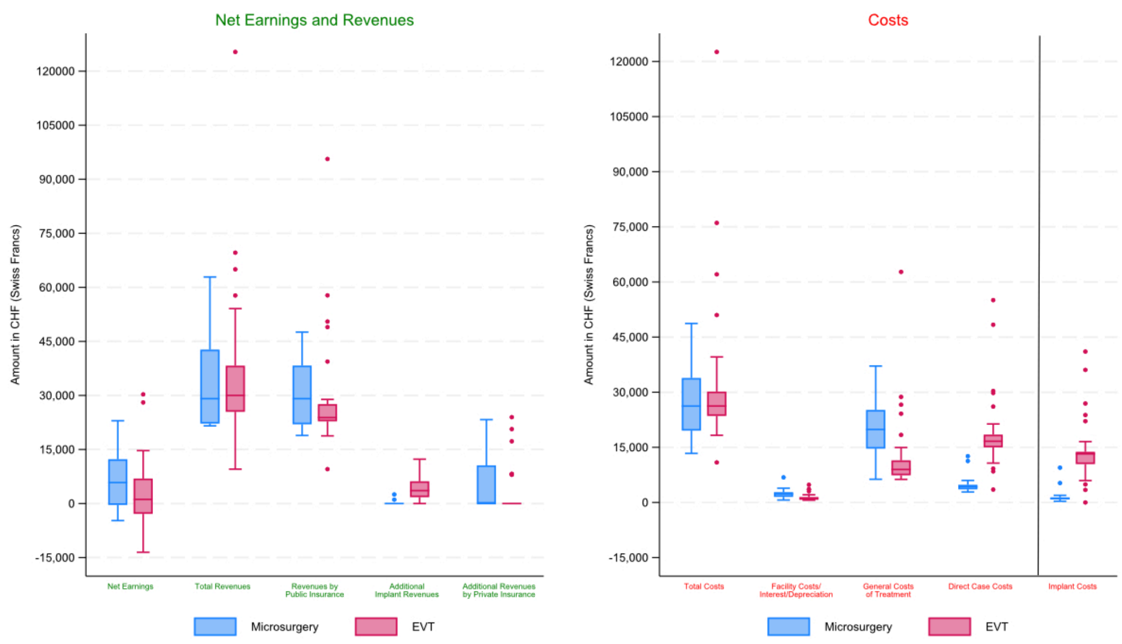
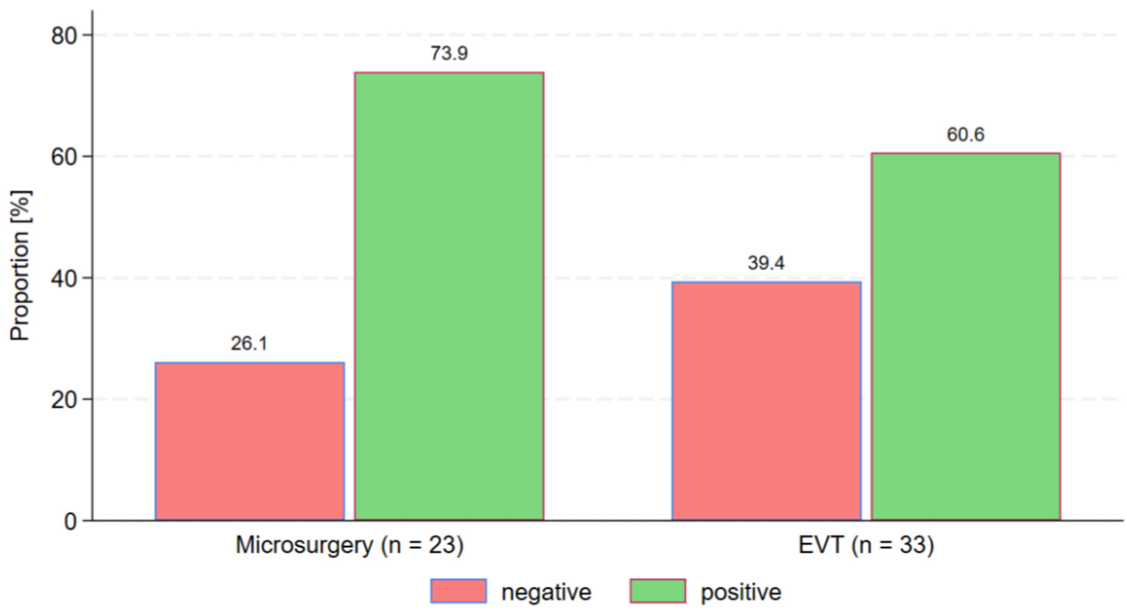



**Figure 2:** Net earnings. A total of 34% of all cases led to a net loss for the hospital. By group, 6 of 23 microsurgery cases (26%) but 13 of 34 endovascular cases (39%) did not close with positive net earnings (p = 0.23). EVT: endovascular treatment.



care system, minimising the risk of financial bias in medical decision-making.

Treatment of unruptured intracranial aneurysm seems to be a highly reimbursed procedure, independent of treatment method. Approximately two thirds of our cases were closed with positive net earnings. Yet, the risk of a case closing with a loss seemed to be higher in the endovascular group (approx. 40% of endovascular cases closed with negative net earnings vs approx. 26% of microsurgery cases). We saw a tendency for cases with higher implant costs to lead to a decline in net earnings. Implant costs were almost exclusively attributed to endovascular treatment. Depending on the implants used, additional reimbursement for certain implants can be requested in these cases. However, our findings suggest that these additional reimbursements did not offset the higher implant costs and may have resulted in a higher risk of negative net earnings. Therefore, based on these findings, further negotiations with the authorities are warranted.

Beyond implant costs, we could not identify factors contributing to net losses in certain cases.

Although almost two thirds of our cases yielded positive net earnings at discharge, we remain with more than a third of all unruptured intracranial aneurysm cases that did not yield a profit but led to a loss of money for our neurocentre and the hospital.

One might assume that there should not be a single case that leads to a loss of money for the hospital or the corresponding treatment unit. This assumption is not necessarily correct. No data exist in the scientific literature that support or contradict the assumption that each case should leave a small profit for the hospital to cover developmental costs. Common sense tells us that there will always be profitable cases and unprofitable cases, and that the latter have to be balanced by the profitable ones. Ultimately, there must be sufficient surplus for the healthcare institutions to cover infrastructure, renovation, depreciation, interest and development.

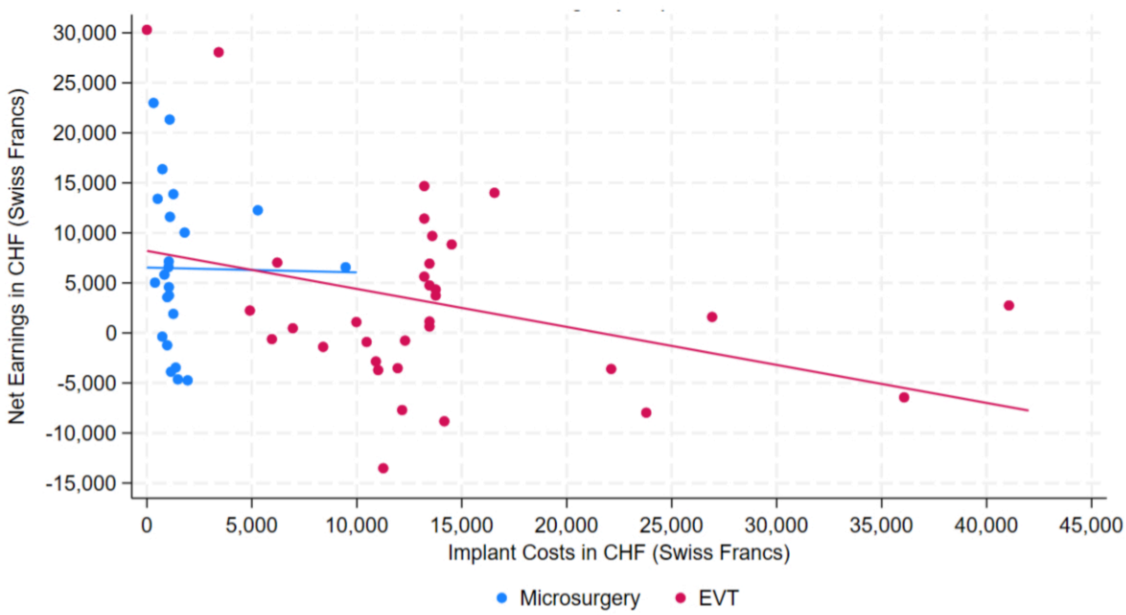
Good care and close monitoring are required for each individual treatment group. The reimbursement should be adequate to prevent substantial loss for hospitals and caregivers. Otherwise there is a risk that gaps in the healthcare will arise as hospitals might no longer be able to provide highly specialised treatments.

On the other hand, close monitoring of highly profitable treatments must be preserved. If certain treatments or diseases regularly lead to high net revenues, individual institutions could "specialise" in them in order to regularly generate high net earnings, which they – in the worst-case scenario – pay out to their shareholders or investors to the detriment of the general public, leaving the less lucrative treatments to public providers.

A theoretical discussion point remains: As endovascularly treated patients had significantly shorter lengths of stay (3.8 vs 7.4 days, approx. 95% longer after microsurgery), one could argue that for every microsurgically treated case, we could instead treat two cases endovascularly to optimise total revenue volume, and thus total earnings. This theory is based on one of the pillars of the DRG system, namely payment by case rather than per time, which provides an incentive for a higher case load. However unlikely this mathematical model seems, it would hold true on a computational basis, given that all aforementioned factors would stay the same if free treatment choice were abolished and all unruptured intracranial aneurysms received endovascular treatment.

Revenue scenarios vary substantially between different healthcare systems so our results do not necessarily reflect a generalisable point of view and must be compared to systems in other countries. In 2009, Hoh et al. evaluated treatment costs of unruptured intracranial aneurysm at the University of Florida and concluded that microsurgical

**Figure 3:** Several factors were evaluated for their correlation with net earnings per case. Single-case net earnings are displayed as dots (blue for microsurgery and red for endovascular) on the Y-axis and correlated with implant costs (on the X-axis). Implant costs in endovascular cases were much more volatile than in microsurgery cases and led to a negative correlation with net earnings (blue regression line). Monetary values are displayed in CHF (Swiss Francs). EVT: endovascular treatment.



treatment was associated with lower hospital costs and higher surgeons' revenues as compared to endovascular treatment [10]. A year later, Drazin et al. came to the same conclusion in their analysis of cases in New York [11]. This finding, from two independent studies, is especially noteworthy, given that in most places in the United States it is the same person who provides microsurgical and endovascular treatment (neurovascular hybrid). A higher personal revenue for a distinct treatment modality might cause significant bias in medical decision-making.

The problem of cases that do not close with positive net earnings has also been addressed before by Brinjikji et al. in the United States. Hospital costs for both treatment methods for unruptured intracranial aneurysm had not been covered by reimbursement from public insurance in almost every single case [4]. Although these numbers might ameliorate our 34% of cases that led to a net loss at discharge, the distinct differences of the two healthcare systems must be addressed; especially the question of who bears the loss of the underpayment found in that study. A hint to that can be found in a study by Lan et al., who concluded that net revenue by private insurance is significantly higher than by public insurance for endovascular unruptured intracranial aneurysm treatment at Vanderbilt University (Nashville, Tennessee, United States) [12].

While in microsurgical clipping, implant costs are usually low (a typical clip in Switzerland costs around CHF 200–300) in relation to the overall costs, implant costs in endovascular treatment vary substantially, depending on the implants used. This is, on the one hand, the type of material (coil, stent/flowdiverter woven endobridge device, etc…), and, on the other hand, the amount used, which depends on the size and complexity of the unruptured intracranial aneurysm. In our data, we saw a high volatility of implant costs in endovascular cases and assume that both aforementioned factors influence the costs. Several studies (one from Mexico, one from Thailand and one from the United States) have addressed this question and found that depending on the type and amount of material used for embolisation, larger or more complex aneurysms had higher implant costs, as expected [1, 13, 14]. As we also saw a tendency towards higher rates of non-profitable cases with rising implant costs, close care must be taken and discussions must follow the implementation of new (or more expensive) devices, for dedicated reimbursement in selected cases, if justified.

Our study did not look at follow-up costs, but at primary treatment costs. Primary treatment costs might have been a decision criterion for the recommendation of a distinct treatment option. Fortunately, within the Swiss healthcare system, this does not seem to be the case. Yet, costs for revision interventions, follow-up images or complication management must also be considered, especially in a population where cure rates (and follow-up costs) might differ between the treatment modalities. Assuming that re-intervention rates are higher in endovascular cases, the cost-balance for a single lesion might additionally be affected in favour of microsurgical treatment. Yet these distinct follow-up costs pose a different question and might be addressed by a different dataset in the future.

From a critical point of view, the rates of patients being discharged to rehabilitation or nursing homes might seem high (17% after microsurgical treatment and 9% after endovascular treatment). However, we routinely offer rehabilitation programmes (also including Kur-Klinik) to patients who receive intracranial (mainly operative) procedures. Thus, a rate of 17% of patients who are reluctant to take advantage of this kind of therapy is well expected after microsurgery. Also, we had three patients in our dataset who had been diagnosed with unruptured intracranial aneurysm during a hospital stay due to other neurological diseases and had therefore been recommended rehabilitation after treatment. The one patient who had died had a previously coiled giant aneurysm of the basilar artery that had already elicited midbrain compression. Re-treatment was associated with intraprocedural bleeding from the aneurysm. Given the poor overall prognosis, therapy goals were changed to comfort therapy after multiprofessional conversations and care for the patient and relatives.

Of course, further treatment (like rehabilitation, Kur-Klinik, etc) do also raise the total costs for the healthcare or even the social system. Yet, they could not be assessed objectively in our dataset.

### Conclusion

Our data show that within the Swiss healthcare system, patients do not have to worry about a financial bias in medical decision-making concerning unruptured intracranial aneurysm treatment. This is reassuring and stresses the well-balanced reimbursement features in this country, whose healthcare system is considered excellent but expensive. Nevertheless, there are threats even for well-balanced and well-financed healthcare systems. Rising costs may lead to imbalanced net earnings or even losses and result in reduced supply of the non-profitable treatments. Also, unequal reimbursements that promote certain treatments or methods can facilitate "cherry picking" which in turn may encourage individual institutions to only carry out well-paid treatments and leave less lucrative treatments to others. We see initial signs of an imbalance with a higher risk for negative net earnings in endovascular cases – probably due to higher and volatile implant costs. This issue is of course highly dependent on the local healthcare system and can even vary within a country (by multiple healthcare options). In any event, two points seem valid across countries: A significant number of cases (even in the high-revenue segments) cannot be closed with positive net earnings. The reasons seem variable, but high implant costs do surely contribute and should therefore be closely monitored.

## Data sharing statement

### Open science code

CHEERS 2022 Checklist items 1–28 were met where applicable. Dedicated applicability per item can be received upon sound and adequate request addressed to ulf.schneider[at]luks.ch and will be available for five years from publication of the study.

Will the individual dataset be available? Yes

What data in particular will be shared: Individual data that underlie the results reported in this article, after deidentification.

What other documents will be available: Not applicable.

When will data be available: Immediately following publication and ending five years following article publication.

With whom: Researchers who provide a methodologically sound proposal.

For what types of analyses: To achieve the aim in the approved proposal.

By what mechanism will data be available: Proposals should be addressed to ulf.schneider[at]luks.ch. To gain data access, data requesters will have to sign a data access agreement. Data are available for five years.

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**Potential competing interests**

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. *AVH* is proctor for Rapid Medical (Comaneci temporary stent) and as such has received an educational grant over CHF 30,000. The other authors stated that they do not have conflicts of interest related to this manuscript to disclose.

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