

Social Impact and Economic Burden of Uncoded Hyponatremia in Elderly – A Cost-of-Illness Study

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Purpose: Hyponatremia remains one of the most prevalent electrolyte disorders among geriatric inpatients but is frequently under-recognized in clinical coding. This *cost-of-illness (COI)* study aimed to (1) estimate the corrected prevalence of uncoded hyponatremia (ucHn) by integrating laboratory and administrative data, and (2) quantify its incremental social and economic burden on elderly patients.

Patients and Methods: A retrospective *COI* analysis covered 72,730 inpatient cases ≥ 70 years (2016–2024) in a Swiss hospital network. Hyponatremia was classified as coded (cHn; ICD-10 E87.1) or uncoded (ucHn; Na < 135 mmol/L). Incremental costs were estimated via generalized linear models and probabilistic sensitivity analysis.

Results: Among 13,657 patients with hyponatremia (18.7%), only 2,070 (2.8%) were coded. Prevalences were as follows: coded 2.8%, hidden 15.9%, true prevalence 18.7%. ucHn was more prevalent in men ($p < 0.0001$), presented with more mild cases (83.1/34.9%, $p < 0.0001$), more incident cases (14.3/4.7%, $p < 0.0001$), lower chronic hyponatremia (20.8/39.6% $p < 0.0001$), significantly more frequent heart failure and lung cancer ($p < 0.0001$), had higher asset cost (2,463 vs 1,654, $p < 0.0001$), lower contribution margin 1 and 2 ($p < 0.0001$) and a markedly higher 30-day mortality (46% vs 7%, $p < 0.0001$). Mean length of stay (LOS) was 9.9 days vs 7.4 days ($p < 0.0001$). ucHn generated incremental costs of CHF per case with a total systemic burden (2016–2024) amounted to ≈ 355 to 473 MCHF. Losses of autonomy, mobility, cognitive control and life years underline the impressive social impact for nearly every ucHn case.

Conclusion: For the first time, the detected ucHn is evaluated. It presents a substantial social and economic burden with a previously unquantified excess mortality associated with uncoded hyponatremia. ucHn is widely underestimated in administrative hospital data. This COI study supports policy measures to improve documentation and awareness of hyponatremia in elderly patients with the aim of reducing its social impact.

Plain Language Summary:

Why was this study done?

Hyponatremia means that the concentration of sodium in the blood is too low, most often because of an excess of water rather than a true lack of sodium. This condition is common in older hospital patients and can cause serious problems like falls, confusion and even death. However, doctors often fail to record this condition in medical files. The researchers wanted to find out how many cases are missed and what this means for patients and hospitals.

What did the researchers do and find?

The team analyzed medical records from over 72,000 patients aged 70 and older at a Swiss hospital between 2016 and 2024. They combined blood test results with hospital records to identify both recorded and unrecorded cases of hyponatremia.

Their findings were striking: while blood tests showed that 13,657 patients (18.7%) had hyponatremia, only 2,070 cases (2.8%) were recorded in their medical files. This means 85% of cases went undocumented.

Patients with unrecorded hyponatremia fared worse than those whose condition was documented. They stayed in hospital longer (9.9 days versus 7.4 days) and their death rate within 30 days was dramatically higher (46% versus 7%). Many lost their independence, mobility, and mental sharpness.

The economic impact was substantial, with unrecorded cases costing Swiss hospitals between 355 and 473 million francs over nine years.

What do these results mean?

This study reveals that unrecorded hyponatremia creates a hidden burden on older patients and healthcare systems. Better awareness and documentation could help doctors recognize and treat this condition earlier, potentially preventing serious complications and saving lives. The findings support the need for improved recording practices in hospitals to ensure patients receive appropriate care.

Keywords: geriatric electrolyte shift, mortality, financial losses, diagnosis-related group, DRG, probabilistic sensitivity analysis, PSA, bottom-up and top-down calculation

Introduction

Hyponatremia, defined as serum sodium <135 mmol/L, is the most common electrolyte disorder in hospitalized patients with a prevalence of 15–30%.^{1,2} In patients ≥ 70 years, the primary target population of this study, prevalence ranges from 5–8% at admission and may increase to 28% during hospitalization.³ Mild forms (130–134 mmol/L) account for 60–85% of cases.⁴ The published data show a preference of hyponatremia in females and with over 75 years of age.^{5,6}

Hyponatremia is associated with substantial morbidity: 20–40% increased fall risk with approximately 50% fracture rate among fallers due to neurological effects and reduced bone density.^{7–9} In-hospital mortality is 9% with 22% readmission within 12 months.^{10,11}

Treatment of hyponatremia is clearly structured for severe cases¹² and also for moderate or mild cases.¹³ There are published data show that up to 60% of these cases remain untreated.¹⁴

The economic burden is considerable: annual treatment costs reach 1.6–3.6 billion USD in the United States and 93 million CHF in Switzerland.^{15,16} Median length of stay (9 days) substantially exceeds SwissDRG calculations (6.8–8 days), resulting in significant hospital deficits.¹⁶ Hyponatremic patients demonstrate up to 99% higher annual costs than normonatremic patients.¹⁷

Despite this clinical and economic significance, substantial discrepancy exists between laboratory-detected and clinically coded cases. ICD-10 coding sensitivity for hyponatremia ranges between only 7–11%, while specificity exceeds 99%.¹⁸ Preliminary Kantonsspital Aarau data demonstrate this “hidden prevalence”: among 8,928 patients ≥ 70 years in 2023, only 372 cases (4%) were coded, while laboratory analyses identified additional 1,152 uncoded cases, indicating actual prevalence of 17.1%—more than double the coded rate.

From a health economics perspective, this coding discrepancy has profound implications beyond institutional reimbursement. Uncoded hyponatremia represents a “hidden burden” that systematically underestimates the true prevalence of this condition in hospitalized populations.¹⁹ Previous epidemiological studies relying on coded data may therefore substantially underestimate disease prevalence, particularly in elderly patients where hyponatremia is most common but also most frequently overlooked. Moreover, hyponatremia is associated with substantial secondary complications including falls, fractures, delirium, prolonged hospital stay and increased mortality—complications that generate considerable direct medical costs beyond the electrolyte disorder itself. These excess costs are severity-dependent, with moderate to severe hyponatremia conferring higher risks than mild cases. However, current cost-of-illness estimates may significantly underestimate the true economic burden by failing to capture uncoded cases.²⁰

Internationally, 27–49% of cases remain unrecognized, particularly without specialized care.²¹ Clinically, inadequate documentation may lead to insufficient attention and preventable complications. Economically, undercoding results in lost DRG revenues, as hyponatremia increases Patient Clinical Complexity Level and reimbursement.²²

This cost-of-illness study therefore pursues three interconnected goals: first, to establish a corrected prevalence estimate of hyponatremia by systematically detecting uncoded cases and analyzing age-specific patterns over 9 years; second, to calculate the true excess costs attributable to hyponatremia by quantifying secondary complications

(falls, fractures, delirium, extended length of stay, mortality) in both coded and uncoded populations. And the third demonstrates the direct social impact of uncoded hyponatremia. By revealing the “hidden prevalence” and its associated costs through analysis of routine clinical data, laboratory results, and multivariate statistics, this investigation aims to provide a more accurate assessment of the societal burden of hyponatremia and inform evidence-based resource allocation in healthcare systems.

Methods

Perspective

The study follows a broad societal perspective based on two aspects: social burden (health and functional outcomes) with the possibility and the probability of massive losses of autonomy, emotional and personal decisiveness and second the economic burden (resource consumption) for the patients with uncoded hyponatremia.

Design

This cost-of-illness analysis is designed as a retrospective cohort study analyzing real-world data from Cantonal Hospital Aarau (KSA), a tertiary care center in Switzerland. The study period spans January 1, 2016, to December 31, 2024 (9 years) for primary analyses, with extended descriptive analyses utilizing data from 2013–2024 (12 years).

Cost-of-Illness Framework

This study employs a prevalence-based cost-of-illness approach to quantify the true economic burden of hyponatremia. By systematically identifying uncoded cases through laboratory data, we aim to establish corrected prevalence estimates that account for the “hidden burden” of unrecognized hyponatremia. Economic analyses capture both direct costs (hospital care, diagnostics, treatment) and costs attributable to hyponatremia-associated complications (falls, fractures, delirium, extended hospitalization).

Study Population and Data Flow

Initial Dataset (2013–2024)

The complete dataset comprised 333,128 inpatient cases. This full dataset was used for descriptive analyses of coding practices and demographic distributions across all age groups.

The restricted cohort of 72,730 patients (≥ 70 years, 2016–2024) ensures data completeness and comparability for economic analyses, which require systematic cost accounting and laboratory data linkage fully implemented only from 2016 onwards. This approach maximizes data utilization while maintaining methodological rigor.

For additional analyses, we constructed a control group comprising 1,800 patients aged ≥ 70 years (200 randomly sampled inpatients per year between 2016 and 2024) with normal serum sodium values. This computer-based simple random sampling ensured an unbiased, time-balanced reference cohort drawn from the same source population as the hyponatremia cases.

Inclusion Criteria

All inpatients aged ≥ 70 years with at least one serum sodium measurement and complete administrative and coding data captured in the hospital information system (KISIM and REDCap).

Exclusion Criteria

Outpatients, patients < 70 years of age, cases from 2013–2015 (incomplete economic data), and cases with missing or incomplete administrative, coding, or laboratory data.

Data Sources and Management

Structured data collection was automated from four primary sources: electronic medical record (KISIM), laboratory information system (all serum sodium measurements), administrative databases hosted on secure hospital server infrastructure. Patient-identifying data were pseudonymized before analysis, accessible only to the principal investigator and

stored separately from analysis data. Data quality was ensured through automated plausibility checks, random sample validation, and duplicate detection via unique patient identifiers.

Mortality data were obtained from the Swiss Federal Statistical Office (BFS) and analysed for the following time intervals: 0–30 days, 30–90 days, 90 days–1 year, 1–5 years, and >5 years after the index hospitalization.

Definitions and Classifications

Hyponatremia: Serum sodium <135 mmol/L according to international standards, classified by severity as mild (130–134 mmol/L), moderate (125–129 mmol/L) or severe (<125 mmol/L). E87.1-coded: Direct ICD-10 coding of hyponatremia as electrolyte disorder.

Classifications

Hyponatremia present on admission (prevalent cases = pHn) versus developing during hospital stay (incident cases=iHn). A third group comprised: chronic hyponatremia (chrHn)] defined as hyponatremia present both in the admission and discharge laboratory measurements. Uncoded hyponatremia (ucHn) was defined as any case with laboratory-confirmed hyponatremia (serum sodium <135 mmol/L) without an ICD-10 code E87.1, whereas coded hyponatremia (cHn) referred to cases with laboratory-confirmed hyponatremia and an E87.1 code.

Primary endpoints:

1. Proportion of laboratory-confirmed but uncoded hyponatremia cases
2. Economic impact measured as difference between actual costs and DRG reimbursement in coded versus uncoded cases (actual costs=direct costs)

Secondary endpoints:

Clinical outcomes:

- Length of stay
- Posthospital mortality
- Readmission
- Falls, fractures, delirium
- Admission to nursing home
- Admission to rehabilitation

Statistical Analysis

Descriptive statistics were used for population characterization and subgroups. Comparative analyses: Chi-square tests compared categorical variables; t-tests or Mann–Whitney *U*-tests (after Shapiro–Wilk normality testing) compared continuous variables between coded and uncoded cases. Age-stratified prevalence rates were calculated for 5-year age bands (70–74, 75–79, 80–84, 85–89, ≥90 years) to identify age-dependent detection patterns.

Total Cost-of-Illness Extrapolation

The aggregate societal burden was estimated by multiplying per-case excess costs (stratified by severity) by the number of uncoded cases in each severity category, summed across all severities and adjusted for complication probabilities.

Multivariate regression models analyzed economic outcomes and determinants of coding behavior, adjusting for age, hyponatremia severity, medications, and procedural factors. Special attention was given to readmissions using pseudonymized patient identifiers to avoid double-counting.

Direct Institutional Impact

Revenues were calculated via DRG reimbursement (SwissDRG system). Cost components included operating costs (physicians, nursing, surgery/anesthesia, diagnostics/therapy, material, medication) and investment costs (administration,

infrastructure). Contribution margins I and II were calculated for profitability analysis. Revenues are given by Case Mix Index (CMI) values and length of stay were compared against DRG catalog values to quantify over- or under-financing in coded versus uncoded hyponatremia cases. Lost DRG revenue due to non-coding was calculated as the difference in expected reimbursement if cases had been appropriately coded.

Complication-Attributable Excess Costs

For uncoded and coded hyponatremia incremental costs associated with complications (falls, fractures, delirium, extended length of stay) were estimated using unit costs from published economic studies.

Total Cost-of-Illness Estimation

The aggregate economic burden of uncoded hyponatremia was calculated by extrapolating per-case excess costs (from matched analyses) across all uncoded cases. The total economic impact included direct cost-revenue differentials, complication-associated costs and lost DRG revenue. To evaluate the total cost of the bottom up calculation we used a detailed probabilistic sensitivity analysis on the basis of the underlying parameters (casemix increment base rate, interest rate, fracture costs, delirium costs, readmission costs, LOS additional costs and mortality costs) and analyzed the robustness.

Mortality

We examined 30 days post, >30–90 days post, >90 days to 1 year, >1 year to 5 years and >5 years post mortality. The cost for death was calculated on the basis of the mean values of a Swiss study (33) as we are not able to allocate the definitive causality of death, we performed a sensitivity analysis for mortality-related costs using three predefined attribution scenarios:

“base case”: 100% attribution, assuming that all end-of-life costs are attributable to hyponatremia

“moderate case”: 75% attribution, assuming that most but not all end-of-life costs are attributable to hyponatremia

“conservative case”: 50% attribution, assuming that half of the end-of-life costs are attributable to hyponatremia.

These attribution shares were treated as modelling assumptions within the probabilistic sensitivity analysis, rather than as exact causal fractions and were taken into calculation matrix (for control group not available).

Ethics and Data Protection

Ethical approval was obtained from the Ethics Committee Northwest and Central Switzerland (EKNZ, Basel, Project-ID 2025–01047). The study complies with the Declaration of Helsinki and Swiss Human Research Act (HFG Art. 34). This study received funding (1410.000.259) from the Forschungsrat Aarau.

Results

Coded Prevalence, Hidden Prevalence and True Prevalence

The primary data from 2013–2024 enclosed 333,128 patients of all age groups with a prevalence of coded hyponatremia of (4,764/ 331,128) 1.4%. The patients aged 70 years and more (n=94,868) delivered 2,702 patients with a coded prevalence was 2.8%. Due to the need of complete data sets for the following analysis, we used data period 2016–2024 and the age group ≥ 70 years. The final cohort of patients ≥ 70 years (n=72,730) consisted of 33,918 (46.6%) women and 38,812 (53.4%) men. The control group were n=1,800 patients ≥ 70 years with normal sodium value (nSv).

In the next step, we assessed coding status: uncoded hyponatremia (ucHn) and coded hyponatremia (cHn). cHn comprised 2,070 patients, while 70,660 patients had no hyponatremia code, yielding a coded prevalence of 2.8%. Based on laboratory data, there were 13,657 cases with confirmed hyponatremia. Uncoded cases (ucHn) added up to 11,587 corresponding to a hidden prevalence of 15.9%. The resulting true prevalence of hyponatremia (coded + uncoded) was therefore approximately 18.7% (Table 1).

Gender, Age And Ageing Groups

ucHn vs cHn vs nSv showed to following distribution: men 51.2% vs 35.2% vs 53.9% ($p < 0.001$) age groups 70–74 (26.9%/19.8%/27.1%), 75–79 (27.4%/24.7%/24.1%) ($p < 0.001$) and fewer were seen in the high aged groups 85–89 (15.9%/20.4%/16.2%) and ≥ 90 (7.6%/11%/7.9%) ($p = 0.001$).

Table 1 Comparison ucHn vs cHn for Prevalence, Gender, Age, Distribution, Clinical Groups, Diagnoses, Departments, LOS (Length of Stay), Types and Cost

Parameter	ucHn (n = 11587)	cHn (n = 2070)	Total (n = 13657)	p-value
Mean age (years $\pm$ SD)	77.2 $\pm$ 6.1	80.4 $\pm$ 5.8	77.8 $\pm$ 6.3	< 0.001
Male sex % (n)	51.2	35.2	48.6	< 0.001
Serum sodium (mmol/L $\pm$ SD)	131.4 $\pm$ 1.9	126.6 $\pm$ 1.3	130.5 $\pm$ 2.3	< 0.001
Severe (<125 mmol/L) %	3.6	27.8	7.7	< 0.001
Moderate (125–129 mmol/L) %	13.4	37.3	17.9	< 0.001
Mild (130–134 mmol/L) %	83.1	34.9	74.4	< 0.001
Chronic cases %	20.8	39.6	24.7	< 0.001
Incident cases %	14.3	4.7	12.5	< 0.001
Prevalent cases %	85.7	95.3	—	—
Coded prevalence (%) all ages			1.4	
Coded prevalence (%) ($\geq$ 70 yrs)			2.8	
Hidden prevalence (%) $\geq$ 70 yrs)			15.9	
True prevalence (%) ($\geq$ 70 yrs)			18.3	
Number Diagnoses	7.92 $\pm$ 2.15	8.24 $\pm$ 1.69	—	<0.001
Heart failure (I50)	30.1%	21.0%	—	< 0.001
Lung cancer (C34)	17.4%	11.5%	—	< 0.001
Pneumonia (J18)	15.9%	21.7%	—	< 0.001
Renal disease (N17–18)	9.1%	15.9%	—	< 0.001
Hematologic disease (C81–C95)	13.9%	12.7%	—	0.04
Metastatic cancer (C79)	8.8%	15.0%	—	< 0.001
Cardiology	8.8%	6.0%	—	< 0.001
General Surgery	5. %	3.8%	—	0.002
Urology	6.0%	3.5%	—	< 0.001
Internal Medicine	13.4%	22.4%	—	< 0.001
Length of stay (days)	9.91 $\pm$ 10.6	7.42 $\pm$ 6.39	—	< 0.001
Case weight (CW)	1.91 $\pm$ 2.51	1.28 $\pm$ 1.28	—	< 0.001
Short stay liar	4.40%	3.2%	—	< 0.001
Profit liar	48.80%	56.00%	—	< 0.001
Cost liar	34.60%	31.40%	—	< 0.001
High outlier	12.30%	9.40%	—	< 0.001
Delirium	10%	5.6%	—	< 0.001
Fracture	24.3%	19.4%	—	< 0.001
Readmission	4.9%	4.6%	—	< 0.001

(Continued)

Table 1 (Continued).

Parameter	ucHn (n = 11587)	cHn (n = 2070)	Total (n = 13657)	p-value
Rehabilitation	11.7%	7.5%	—	< 0.001
Nursing Home	5.6%	6.3%	—	< 0.001
Operating cost (CHF)	21,090±27,105	13,376±14,586	—	< 0.001
Asset cost (CHF)	2,463 ± 2988	1,654 ± 1641	—	< 0.001
Revenue (CHF)	20,594±26,496	13,920±14,814	—	< 0.001
CB 1 (Contribution Margin 1) (CHF)	− 545 ± 13,592	+ 527 ± 8,944	—	< 0.001
CB 2 (Contribution Margin 2) (CHF)	− 3,009 ± 602	− 1,117 ± 442	—	< 0.001

The mean age was 79.69 ± 6.4 years for control (n=1,800, median 79, minimum 70, maximum 100), 79.47 ± 6.4 years for ucHn (median 79, minimum 70, maximum 101) and 80.4 ± 5.8 years for cHn (median 80, minimum 70, maximum 99). The control group showed nearly the same age groups ($p=0.043$) and gender (0.03) distributions as the differences between ucHn and control group were not strongly significant (Table 1).

Distribution of the Sodium Groups

The sodium values in total were mean 130.8 ± 1.82 mmol/L. The ucHn sodium values were 131.4 ± 1.91 mmol/L (n=11,587). For cHn we found 126.6 ± 1.28 mmol/L (n=1,720). The differences were significant ($p<0.001$).

Three hyponatremia groups were defined: severe (<125 mmol/L), moderate (125–129 mmol/L) and mild (130–134 mmol/L). The distribution over the 13,657 patients showed the following results: severe group: 6.7% (mean 119 ± 5.3 mmol/L, median 122 mmol/L, min. 62 mmol/L, max 124 mmol/L). Moderate group: 16.5% (mean 127 ± 1.3 mmol/L, median 128 mmol/L, min. 125 mmol/L, max 129 mmol/L). Mild group: 76.8% (mean 133 ± 1.6 mmol/L, median 134 mmol/L, min. 130 mmol/L, max 135 mmol/L).

ucHn versus cHn was in the severe group 3.6% (n=413) versus 27.8% (n=478), in the moderate group 13.4% (n=1,549) versus 37.3% (n=641) and in the mild group 83.1% (n=9,625) versus 34.9% (n=601). The results were significantly different ($p<0.001$). Due to the high number of uncoded hyponatremia cases, the severe ucHn group with only 3.6% produced nearly the same number of patients as cHn with 27.8% (ucHn 413 versus cHn 478) (Table 1). ucHn versus cHn had significantly lesser cases of chronic hyponatremia in all three groups (severe 38.3%/50%, moderate (33.6%/44.0%) mild (18%/26.6%) ($p<0.001$, Table 1).

Clinical Groups: Prevalent, Incident and Chronic Hyponatremia

We defined three clinical groups of hyponatremia (n=13,657 cases). Prevalent hyponatremia (pHn) was defined as a laboratory confirmed hyponatremia on admission day and day 2 (because some laboratory data are done at the second day eg. elective patients). pHn were n=11,572 cases. Chronic hyponatremia (chrHn) was defined as a hyponatremia found both in the admission and the discharge laboratory. chrHn were 3,088 cases which were found in the prevalent group. Incident Hyponatremia (iHn) was defined as a laboratory confirmed hyponatremia found with the beginning of day 3 after admission. iHn were 1,735 cases. For ucHn, we found significantly more incident cases: 14.3% versus 4.7% ($p<0.001$, Table 1). Chronic Hyponatremia was distributed with 20.8% in ucHn and 39.6% in cHn with a significant difference ($p<0.001$; Figure 1).

Target Diagnoses

For ucHn, significantly more diagnoses per patient were recorded (7.92 ± 2.15 vs 8.24 ± 1.69 in cHn, $p<0.001$). The control group (nSv) had 6.14 ± 2.45 diagnoses ($p<0.001$).

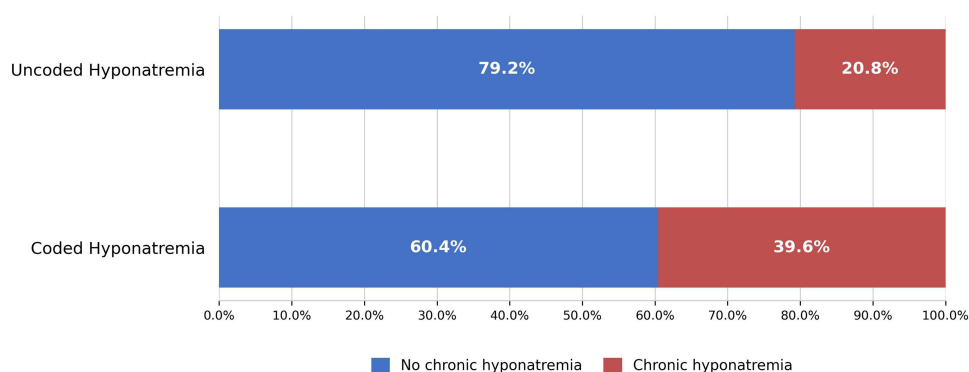


Figure 1 Distribution of Chronic Hyponatremia in the Coded (cHn) And Uncoded Group (ucHn), red= chronic hyponatremia, blue=no chronic hyponatremia.

To analyze the relationship between the main diagnoses and hyponatremia in ucHn and cHn, we examined the following ICD groups: heart insufficiency (I50), pneumonia (J18), liver cirrhosis (K74), renal diseases (N17/N18), SCLC lung carcinoma (C34), CNS-tumors (C71), metastatic tumors (C79), hematologic disease (C81-C95).

ucHn vs cHn vs nSv presented with significant differences in heart insufficiency (30.1%/21.0%/15.56%), lung carcinoma (17.4%/11.5%/3%) and a significantly lower percentage for pneumonia (15.9%/21.7%/3%), renal insufficiency (9.1%/15.9%/25%), hematologic diseases (13.9%/12.7%/1%) and metastatic carcinoma (8.8%/15%/4%; $p < 0.001$, Tables 1 and 2).

Table 2 Comparison ucHn vs Control Group for Prevalence, Gender, Age, Distribution, Clinical Groups, Diagnoses, Departments, LOS (Length of Stay), Types and Cost

Parameter	ucHn (n = 11587)	Control (n=1800)	p-value
Mean age (years $\pm$ SD)	79.47 $\pm$ 6.4	79.69 $\pm$ 6.4	< 0.001
Age Groups Comparison			0.043
Male sex % (n)	51.2 (5930)	53.9 (970)	0.03
Serum sodium (mmol/L $\pm$ SD)	131.4 $\pm$ 1.9	>135	< 0.001
Number Diagnoses	7.92 $\pm$ 2.15	6.14 $\pm$ 2.45	<0.001
Heart failure (I50)	30.1%	15.56%	< 0.001
Lung cancer (C34)	17.4%	3%	< 0.001
Pneumonia (J18)	15.9%	3%	< 0.001
Renal disease (N17–I8)	9.1%	25%	< 0.001
Hematologic disease (C81–C95)	13.9%	1%	< 0.001
Metastatic cancer (C79)	8.8%	4%	< 0.001
Cardiology	8.8%	12%	< 0.001
General Surgery	5.8%	3%	0.002
Urology	6.0%	7%	< 0.001
Internal Medicine	13.4%	20%	< 0.001

(Continued)

Table 2 (Continued).

Parameter	ucHn (n = 11587)	Control (n=1800)	p-value
Length of stay (days)	9.91 ± 10.6	7.09 ± 7.55	< 0.001
Case weight (CW)	1.91 ± 2.51	1.35 ± 8.14	< 0.001
Short stay lier	4.40%	6%	< 0.001
Profit lier	48.80%	52%	< 0.001
Cost lier	34.60%	30%	< 0.001
High outlier	12.30%	10%	< 0.001
Delirium	10%	3.7%	< 0.001
Fracture	24.3%	9.6%	< 0.001
Readmission	4.9%	7.3%	< 0.001
Rehabilitation	11.7%	7.6%	< 0.001
Nursing Home	5.6%	4.5%	< 0.001
Operating cost (CHF)	21,090±27,105	12,235±16,607	< 0.001
Asset cost (CHF)	2,463 ± 2,988	1,474± 1,848	< 0.001
Revenue (CHF)	20,594± 26,496	14,499±1,848	< 0.001
CB 1 (Contribution Margin 1) (CHF)	– 545 ±13,592	2,262± 9,286	< 0.001
CB 2 (Contribution Margin 2) (CHF)	– 3,009 ±14,602	788±9,623	< 0.001

Departments

To analyze the relationship of department and the coding of hyponatremia we analyzed the following departments: Cardiology, General Surgery, Internal medicine, Urology, Neurology, Neurosurgery, Traumatology, Orthopedics, Eye surgery, ENT, Gynecology.

ucHn vs cHn vs nSv presented a significantly higher percentage of uncoded hyponatremia in Cardiology (8.8%/6.0%/12%), General Surgery (5.8%/3.8%/3%), Vascular Surgery (3.8%/0.4%/2.7%), ENT (1.6%/0.6%/3.1%), Urology (6%/3.5%/7%) with $p<0.001$. Whereas, chn was higher in Orthopedics (6.5%/8.7%/8.7%), Neurosurgery (7.6/9.9%/6.7%), Internal Medicine (13.4%/22.4%/20%) (Tables 1 and 2).

Length of Stay (LOS), Length of Stay Outlier Classification, Case Weight (CW)

ucHn vs cHn vs nSv presented for LOS: +2.82 days (9.91± 10.6 vs 7.42± 6.39 vs 7.09± 7.55 days) with $p<0.001$. For descriptive purposes, we further categorized cases as short-stay outliers (below the lower DRG trim point), inliers (within the normal DRG length-of-stay range), and long-stay outliers (above the upper trim point). Short-stay outliers accounted for 4.3%/3.2%/6.1% of cases in ucHn/cHn/nSv, inliers for 47.5%/56.0%/52.5%, and long-stay outliers for 34.5%/31.4% / 30.2% plus 12.3%/9.4%/9.6%, respectively (all $p<0.001$).]

For ucHn vs chn vs nSv the CW was (1.91± 2.51/ 1.28±1.28/1.35±1.69) with $p<0.001$ and a maximum difference of 0.56 CMP. For ucHn versus cHn the LOS vs. catalogue LOS was 1.35±8.14 versus 0.39±5.3days with $p<0.001$ (Table 1).

Cost

All costs were measured in CHF. We analyzed operational costs, asset costs, sales revenues and the contribution margins 1 and 2. Operating and asset costs were significantly ($p<0.001$) different in ucHn vs cHn vs nSv: operating cost 21,090±27,105/ 13,376±14,586/12,235 ± 16,607 and asset cost: 2,463±2,988/1,654±1,641/1,474±1,848). Sales revenues were significantly

different in ucHn vs cHn vs nSv: revenues 20,594±26,496/13,920±14,814/ 14,499±1,848CHF) with the highest in ucHn. Contribution margins 1 and 2 were significantly different ($p<0.001$) ucHn vs cHn vs nSv CB 1: -545±13,592/527±8,944/ 2,262±9,286) and CB 2: -3,009±14,602/-1,117±9,442/788±9,623) the lowest in ucHn. (Tables 1 and 2).

Losses Due to Uncoding and Longer LOS

The amount of 11,587 cases with laboratory confirmed hyponatremia was not coded. To calculate the delta revenue loss, we need the base rate of the specific year in the Kanton Aargau.²³ The calculation was made with an interest rate of 5%. The duration was 9 years. It was assumed that coding E87.1 would yield a mean PCCL level augmentation of 1 to 4 points, dependent on the primary DRG, with a leverage effect of 0.4 to 1.0 CMP. We used it for the calculation of 0.4CMP. With a prolongation of +2.82 days (to control group) we can calculate the losses (adapted day cost). All in all, we can summarize the cost through LOS of -36.1MCHF in the study period (Table 3).

Medication*

We found beta blocking agents (9.5%/9.1%), pantoprazole (11.0%/10.6%), morphine (6.3%/3.5%) and deltaparin (20.5%/19.5%) in significantly higher numbers in ucHn than in cHn ($p<0.001$). In total the daily taken number of medication was significantly higher in ucHn than in cHn. For the top 10 of medication in ucHn and cHn we found a total cost (calculated on the basis of API price) of 1.17 versus 0.7 MCHF (Table 4).

For the purpose of cost standardization, all monetary values were normalized using a 1:1 USD–CHF conversion factor. This simplifying assumption reflects the minor and stable exchange rate variation between the Swiss franc and the U.S. dollar over the study period and allows for direct international comparison of expenditure data. Sensitivity analyses using ±20% variation in exchange rates confirmed the robustness of the calculated cost differentials (Table 5) (no data for the nSv).

Table 3 Calculation of Lost Sales Due to Uncoding * and Additional Cost Due to LOS **

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	Sum
BR/CHF	9,400 to 9,700	9,450	9,400 to 9,500	9,450	9,500	9,550	9,650 to 9,700	10,200	10,400 to 10,500	
Calculated Baserate	9,550	9,450	9,450	9,450	9,500	9,550	9,675	10,200	10,450	
Cases	1,126	1,307	1,210	1,282	1,212	1,164	1,407	1,738	1,124	11,570
Casemix +0,4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
cHn	3,820	3,780	3,780	3,780	3,800	3,820	3,870	4,080	4,180	
Sum (MCHF)	4.3	4.94	4.57	4.85	4.61	4.45	5.45	7.09	4.7	
Interest 5%	1.55	1.48	1.41	1.34	1.28	1.22	1.16	1.1	1.05	
Duration (years)	9	8	7	6	5	4	3	2	1	45
Interest Income (MCHF)	2.37	2.37	1.88	1.65	1.29	0.98	0.87	0.71	0.23	12
Final Yield (MCHF)	6.67	7.31	6.45	6.49	5.9	5.42	6.32	7.8	4.93	57.29*
Cases ucHn	1,126	1,307	1,210	1,282	1,212	1,164	1,407	1,738	1,124	11,570
LOS	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	
Day cost (CHF)	-1,097	-1,085	-1,085	-1,085	-1,091	-1,097	-1,111	-1,171	-1,200	
Sum LOS (CHF)	-3,093	-3,059	-3,059	-3,059	-3,076	-3,093	-3,133	-3,302	-3,384	
Sum LOS total (CHF)	-3.48	-4.00	-3.70	-3.92	-3.73	-3.60	-4.41	-5.74	-3.80	-36.39**

Notes: Calculation: Having placed the annual sum on the finance market with an interest rate of 5% would have produced the final yield of 57.29MCHF (Million Swiss Francs). This sum is the calculated lost sales due to uncoding. 0.4CMP (Case Mix Point) per case was found as a lowest value being result of a simulation with the medical coding team (0.4–1.0CMP/case with additional coding of E87.1). Calculation of additional loss due to LOS was made with year adapted day cost multiplied with the prolonged length of stay.

Table 4 Medication, Daily Doses and Total Cost in Uncoded and Coded Hyponatremia

Substance	Status	Patients	LoS	Daily Dose (mg)	API Price (USD/kg)	Total Cost (USD)
Pantoprazole (proton pump inhibitor)	Uncoded	1,144	9.91	40	51,000	23,127.56
Metoclopramide (antiemetic)	Uncoded	387	9.91	30	44,000	5,062.42
Insulin lispro (rapidacting- insulin)	Uncoded	754	9.91	40	600,000	179,331.36
Dalteparin (low molecular weight heparin)	Uncoded	2,132	9.91	50	12,000	12,676.87
Amlodipine (calcium channel blocker)	Uncoded	2,252	9.91	5	70,000	7,780.14
Metoprolol (beta-blocker)	Uncoded	984	9.91	100	57,000	55,583.21
Morphine (opioid analgesic)	Uncoded	652	9.91	60	18,000	6,978.23
Quetiapine (neuroleptic/antipsychotic)	Uncoded	1,084	9.91	100	35,000	37,678.94
Lorazepam (benzodiazepine)	Uncoded	524	9.91	2	86,000	895.39
Paracetamol (analgesic)	Uncoded	1,286	9.91	3	22,000	846,124.52
Pantoprazole (proton pump inhibitor)	Coded	160	7.41	40	51,000	2,418.62
Metoclopramide (antiemetic)	Coded	57	7.41	30	44,000	557.53
Insulin lispro (rapid-acting insulin)	Coded	69	7.41	40	600,000	12,270.96
Dalteparin (low-molecular-weight heparin)	Coded	295	7.41	50	12,000	1,311.57
Amlodipine (calcium channel blocker)	Coded	206	7.41	5	70,000	537.13
Metoprolol (beta-blocker)	Coded	137	7.41	100	57,000	5,786.47
Morphine (opioid analgesic)	Coded	53	7.41	60	18,000	424.15
Quetiapine (neuroleptic/antipsychotic)	Coded	178	7.41	100	35,000	4,619.94
Lorazepam (benzodiazepine)	Coded	52	7.41	2	86,000	66.25
Paracetamol (analgesic)	Coded	98	7.41	3	22,000	48,045.24

Notes: Presentation of the top 10 medication for uncoded and coded hyponatremia, there were no information for the control group.

Table 5 Sensitivity Analysis with Exchange Rate

Sens. Analysis	-20% Scenario (CHF)	Base 1:1 (CHF)	+20% Scenario (CHF)
Pantoprazole	20,437	25,546	30,655
Metoclopramide	4,496	5,620	6,744
Insulin lispro	153,282	191,602	229,923
Dalteparin	11,191	13,988	16,786
Amlodipine	6,654	8,317	9,981
Metoprolol	49,096	61,370	73,644
Morphine	5,922	7,402	8,883
Quetiapine	33,839	42,299	50,759
Lorazepam	769	962	1,154

(Continued)

Table 5 (Continued).

Sens. Analysis	-20% Scenario (CHF)	Base 1:1 (CHF)	+20% Scenario (CHF)
Paracetamol	715,336	894,170	1,073,004
Total	1,001,021	1,251,276	1,501,532

Notes: This table demonstrates that even with a variation of $\pm 20\%$ in the exchange rate, the cost distribution and ranking among drugs remain stable. The overall result and substance-specific order are robust and reliable for international reporting and decision models.

Social Impact of Uncoded Hyponatremia

For patients with ucHn, the study demonstrates 6,810 deaths, meaning a loss of about 30,000 life years,²⁴ loss of mobility with a number of 2,070 new fractures,²⁵ loss of autonomy with 651 nursing home admissions, loss of cognitive control and decisiveness through 1,163 delirant states and 570 new admission with the above mentioned problems. That are 12,600 adverse events in 11,587 patients – so every ucHn case will experience one problematic outcome situation (Table 6).

Distribution of Mortality and Different Attributions *

Total cumulative all-cause mortality over the observation period was $7,725/13,657 \approx 56\%$. Mortality among ucHn patients was $6,810/11,587 \approx 58.7\%$, whereas cHn patients had $915/1,720 \approx 53.3\%$ deaths; these differences were statistically significant. ucHn patients showed consistently higher mortality across all predefined time intervals (0–30 days, 30–90 days, 90 days–1 year, 1–5 years, >5 years), with 46%, 8%, 10%, 18% and 4% of deaths occurring within these periods, compared with 7%, 1%, 2%, 3% and 1% in cHn (all $p < 0.001$). This reflects cumulative mortality over up to more than 5 years in a very old, multimorbid population. The results are given graphically in the Kaplan Meier curve (Table 7 and Figure 2).

The Kaplan Meier curves for 90 days for the three groups coding status, severity and type of hyponatremia clearly show that uncoded, moderate and chronic hyponatremia show the highest mortality (Figure 2). In comparison to the mean life time in Switzerland of 84 years the ucHn patients have a loss of about 4.5 years, meaning $6810 * 4.5 \text{ years} = 30,000$ life years. Associated total mortality costs using CHF 35,000 per death.^{24,26} For different calculations, we used the model “base” with 236 MCHF, “moderate” with 177 MCHF and “conservative” with 118 MCHF for ucHn. (no data for nSv).

Secondary Cost of ucHn

Fractures: In international health economic modeling, to avoid double counting, costs of falls that lead to fractures are fully incorporated within the fracture event²⁵ while only falls without fractures are treated as a separate cost entity²⁵ since counting both together would attribute the same causal pathway twice in economic evaluations. As falls appear nearly

Table 6 Social Impact of ucHn; That are 12,600 Adverse Events in 11,587 Patients

Outcome	n	%	Social Significance
Death	6,810	58.7	~30,000 life years lost
Nursing home	651	5.6	Loss of independent living
Fracture	2,070	17.9	Loss of autonomous mobility
Delirium	1,163	7.4	Loss of cognitive Control
Readmission	570	4.9	Treatment failure, additional suffering
Rehabilitation	1,362	11.7	Functional dependence

Table 7 Distribution of Mortality and Different Attributions in ucHn and cHn

Mortality Interval	Deaths ucHn	Cost ucHn (MCHF)	Deaths cHn	Cost cHn (MCHF)	P value
≤30 days	1,501	52.54	125	4.375	< 0.001
>30 and ≤90 days	889	31.12	96	3.36	< 0.001
>90 and ≤365 days	1,380	48.3	207	7.2	< 0.001
>365 and ≤5 years	2,429	85.02	383	13.4	< 0.001
More than 5 years	558	19.53	103	3.6	< 0.001
Sum attribute base (100%)	–	236	–	32	
Sum attribute moderate (75%)	–	177	–	24	
Sum attribute conservative (50%)	–	118	–	16	

Notes: Attribution means the percentage of responsibility for death through hyponatremia. Conservative assumes that only 50% of the death events are lastly caused by hyponatremia.

always in combination with fractures, we found the same amount of codings for them. ucHn presented with higher fractures/falls (24.3%/19.4%) – control group 9.6%. Falls without fracture are not existing in the coded cases, perhaps they disappear in the codings of other diseases.

The average direct costs of around €23,000 per patient aged over 70 represent the internationally recognized reference basis for the economic evaluation of fractures in this age group. For Swiss conditions, the corresponding cost-level multiplier is approximately 1.2 to 1.3 times the EU value, equivalent to about 27,000 to 30,000 CHF per fracture case, based on a 1:1 currency comparison with the USD exchange rate. Falls ucHn 2,826 cases = 76.3 MCHF/USD and falls cHn with 402 cases = 10.8 MCHF/USD. Difference 65.5 MCHF/USD.

Delirium: ucHn present with higher number of delirant states/cognitive decline than cHn (10%/5.6%) ($p < 0.001$). Control group with 3.7%, differences were significant. The recommended baseline value for economic calculations is 10,000–15,000 USD/EUR/CHF per delirium episode as a realistic central estimate of direct inpatient excess costs, while international publications report a plausible range of 1,500–25,000 USD (or 1,300–23,000 EUR/CHF) per case; for Germany and Switzerland, most estimates lie between 10,000 and 20,000 EUR/CHF per delirium, with higher values observed in intensive care settings. We took 15,000CHF as calculatory baseline.²⁷

Delirium ucHn 1,163 cases = 17.4MCHF/USD and delirium cHn 117 cases = 1.75 MCHF/USD. Difference 15.6MCHF/USD.

Admission Cost Calculation

Admission

The Pearson chi-square test indicating significant differences ($p = 0.002$) between ucHn, cHn and nSv for the parameter coming from nursing home (8%/9%/9%), another hospital (10.2%/10.1%/11.5%) and from home (77%/78%/74.9%).

Readmission, Nursing Home And Rehabilitation

Readmission

ucHn presented 570 (4.9%) cases and cHn 96 (4.6%) cases. Differences were significant ($p < 0.001$). The control group had 131 cases (7.3%). Readmission cost: for rehospitalization costs in geriatric patients with hyponatremia, we used a reference value of approximately CHF 10,000–12,000 per readmission case in our cost calculations. This corresponds to the SwissDRG base rates for internal medicine and acute geriatric cases under typical diagnostic-related grouping. ucHn $570 \times 10,000 = 5.7\text{MCHF/USD}$ and cHn $96 \times 10,000 = 0.96\text{MCHF/USD}$. (Table 8).^{23,28}

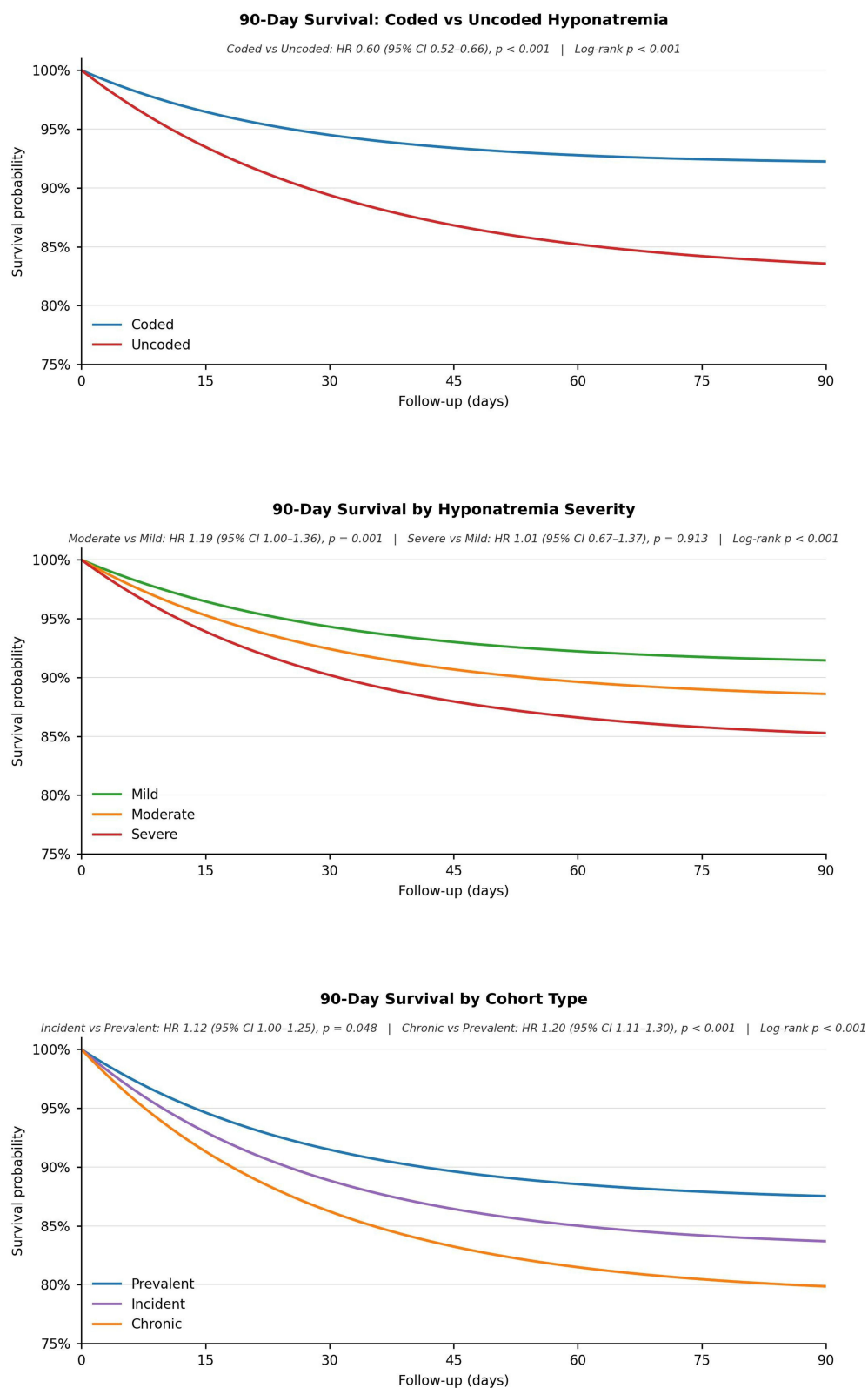


Figure 2 Kaplan Meier Curves for Coding status, Hyponatremia Severity and Cohort Type.

Table 8 Total Hidden Burden of ucHN and Probabilistic Sensitivity Analysis

Cost	Cost Driver	ucHN Base Mean (MCH)	Cost per ucHN case (CHF)	Modeled Range ($\pm$ SD %)	Distribution Type	Simulated Mean (MCHF)	95% CI (MCHF)	Contribution to Variance (%)
Primary Cost	LOS extension (+ 2.72 days)	36.30	3,140	$\pm$ 18.2%	Normal	90.87	58.45–123.04	22.8%
	Medication (top 10 agents)	1.09	94	$\pm$ 0%	Fixed	1.09	—	0.0%
Opportunity Cost	Lost DRG-coded revenue (E87.1)	57.29	4,944	$\pm$ 21.7%	Triangular +Normal	85.43	54.87–127.33	28.7%
Secondary Cost	Falls & Fractures	65.00	5,610	$\pm$ 2.9%	Uniform	68.60	65.34–71.87	0.3%
	Delirium/Cognitive decline	17.40	1,501	$\pm$ 8.3%	Triangular	17.43	14.65–20.18	0.2%
	Readmission	5.70	491	$\pm$ 5.2%	Uniform	6.27	5.74–6.80	0.0%
	Nursing home placement	39.70	3,426	$\pm$ 15.2%	Normal	39.74	27.91–51.74	3.0%
	Rehabilitation	20.43	1,764	$\pm$ 0%	Fixed	20.43	—	0.0%
	Mortality-related cost	236.50	20,410	$\pm$ 9.7%	Normal	238.16	193.08–283.41	44.9%
	Total Cost (ucHN)	479.41	41,379	$\pm$ 6.2%	Monte Carlo (10,000 runs)	568.02	500.23–637.85	100.0%

Notes: The mean total incremental burden for ucHN is estimated at 479 MCHF. The standard deviation across 10000 simulations is 34.70MCHF. The 95% confidence interval for the total excess cost spans 500.23–637.85MCHF. This analysis shows that, given reasonable parameter uncertainty for each major cost driver (lost DRG revenue, LOS extension, drugs, complications, institutional care, and mortality), the cumulative cost impact of uncoded hyponatremia will almost certainly exceed 479 MCHF.

Nursing Home Admission

ucHN showed 651 (5.6%) cases and cHN 131 (7.6%) cases. Differences were significant ($p < 0.001$). The control group had 81 cases (4.5%). For uncoded hyponatremia, only a minority of patients survived long enough after hospital discharge to incur nursing home costs, keeping the expected first-year expenditure per patient of 100,000–120,000CHF lower. With the expected first-year mortality, we calculated 50% of these costs, meaning 50% of 120,000 CHF = 60,000CHF * 651 patients = 39.7MCH.²⁹ Swiss costs and rates reflect slightly higher local expenditures compared to european averages but the mortality-adjusted calculations highlight the dominant effect of survival on long-term institutional finance (Table 8).

Rehabilitation

ucHN showed 1,362 (11.7%) cases and cHN showed 156 (7.5%) cases. Differences were significant ($p < 0.001$). The control group had 136 cases (7.6%). Rehabilitation Cost: for calculation, we used a mean value for geriatric rehabilitation in Switzerland with 15,000CHF. ucHN 15,000*1,362=20.43MCHF (Table 8).

Total Economic Burden of ucHN and the Probabilistic Sensitivity Analysis (PSA)

Based on the COI study file, the hidden economic burden of uncoded hyponatremia (ucHN) was expressed both in total monetary terms and on a per-case basis. The data summarizes the total financial impact (in million CHF, MCHF) and calculates the mean cost per ucHN case, using a total of 11,587 ucHN cases during 2016–2024. There was a total incremental cost of 479MCHF for ucHN. This sum consists of primary cost (37.39 MCHF) defined as prolonged length of stay and medication, opportunity cost defined as losses due to uncoded hyponatremia (57.29 MCHF) and secondary cost defined as falls, fracture, delirium, readmission, nursing home placement and mortality-related cost (384.37MCHF) (Table 8). With the three defined death categories “base”, “moderate” and “conservative” we received 41,379 CHF, 36,247 CHF and 31,155 CHF cost per case.

To evaluate this result and the underlying calculations of the different areas and inherent parameters, we followed published recommendations^{30–32} to test the stability of these estimates with a probabilistic sensitivity analysis (10,000 Monte Carlo iterations) performed across all major categories. Appropriate probability distributions were defined for the parameters casemix increment base rate, interest rate, fracture costs, delirium costs, readmission costs, LOS additional costs and mortality costs.

The distribution of total incremental costs showed a narrow range around the base-case estimate (95% CI 467.84–600.58; mean $\approx$ 532.93 MCHF). The comparison between the influence of cost versus uncertainty showed main cost influence in mortality, whereas the main uncertainty was produced by the coding procedure (Table 8).

Factors Associated with Hyponatremia in Elderly Patients

We pursued a comprehensive analysis of factors associated with hyponatremia coding status. Variables with odds ratios <0.6 were considered strong negative predictors of coding (ie. associated with a higher likelihood of remaining uncoded).

- Incident hyponatremia (OR = 0.36): new-onset cases were 64% more likely to remain uncoded.
- 30-day mortality (OR = 0.50): patients who died within 30 days were 50% more likely to have hyponatremia uncoded.
- Heart failure (OR = 0.50): patients with heart failure were 50% more likely to remain uncoded.
- Lung cancer (OR = 0.54): 46% more likely to be uncoded
- Metastatic cancer (OR = 0.60): 40% more likely to be uncoded (Figure 3).

The Uncoded Patient Profile

The analysis reveals a concerning paradox: patients at highest risk for adverse outcomes are disproportionately likely to have hyponatremia uncoded.

The typical uncoded patient profile includes:

1. Incident (new-onset) hyponatremia
2. Age 70–74 years
3. Serious comorbidities (heart failure, malignancy)
4. Elective admission
5. Early mortality risk

Linear Regression Associated With Coding and Operating Costs

We conducted two complementary regression analyses to examine (1) factors associated with hyponatremia coding status and (2) determinants of operating costs. Both models included 13,291 elderly patients (more than 69 years) hospitalized between 2016 and 2024, with 1,720 (12.9%) coded and 11,571 (87.1%) uncoded cases.

Strong Negative Predictors (Lower Odds of Coding):

- Heart Failure (strongest negative predictor): OR = 0.44, 95% CI [0.36, 0.53], $p < 0.001$. Interpretation: Heart failure patients are 56% less likely to have hyponatremia coded. This suggests diagnostic overshadowing where cardiovascular conditions dominate coding priorities.
- 1-Year Mortality: OR = 0.68, 95% CI [0.59, 0.78], $p < 0.001$. Interpretation: Patients who died within one year are 32% less likely to have hyponatremia coded, indicating systematic under-coding in critically ill or palliative patients.
- Lower Sodium Minimum: OR = 0.87 per mmol/L, 95% CI [0.85, 0.90], $p < 0.001$. Interpretation: Counterintuitively, each 1 mmol/L decrease in sodium reduces coding odds by 13%. However, this is controlled for severity categories, suggesting within severity variation.
- Case Mix Index: OR = 0.87, 95% CI [0.82, 0.92], $p < 0.001$. Interpretation: Higher complexity (CMI) paradoxically reduces coding odds by 13%, possibly reflecting competing diagnostic priorities in complex patients.
- Length of Stay: OR = 0.98 per day, 95% CI [0.97, 0.99], $p < 0.001$. Interpretation: Longer stays slightly reduce coding odds (2% per day), potentially due to resolution before discharge or focus shift to primary diagnoses. (Table 9).

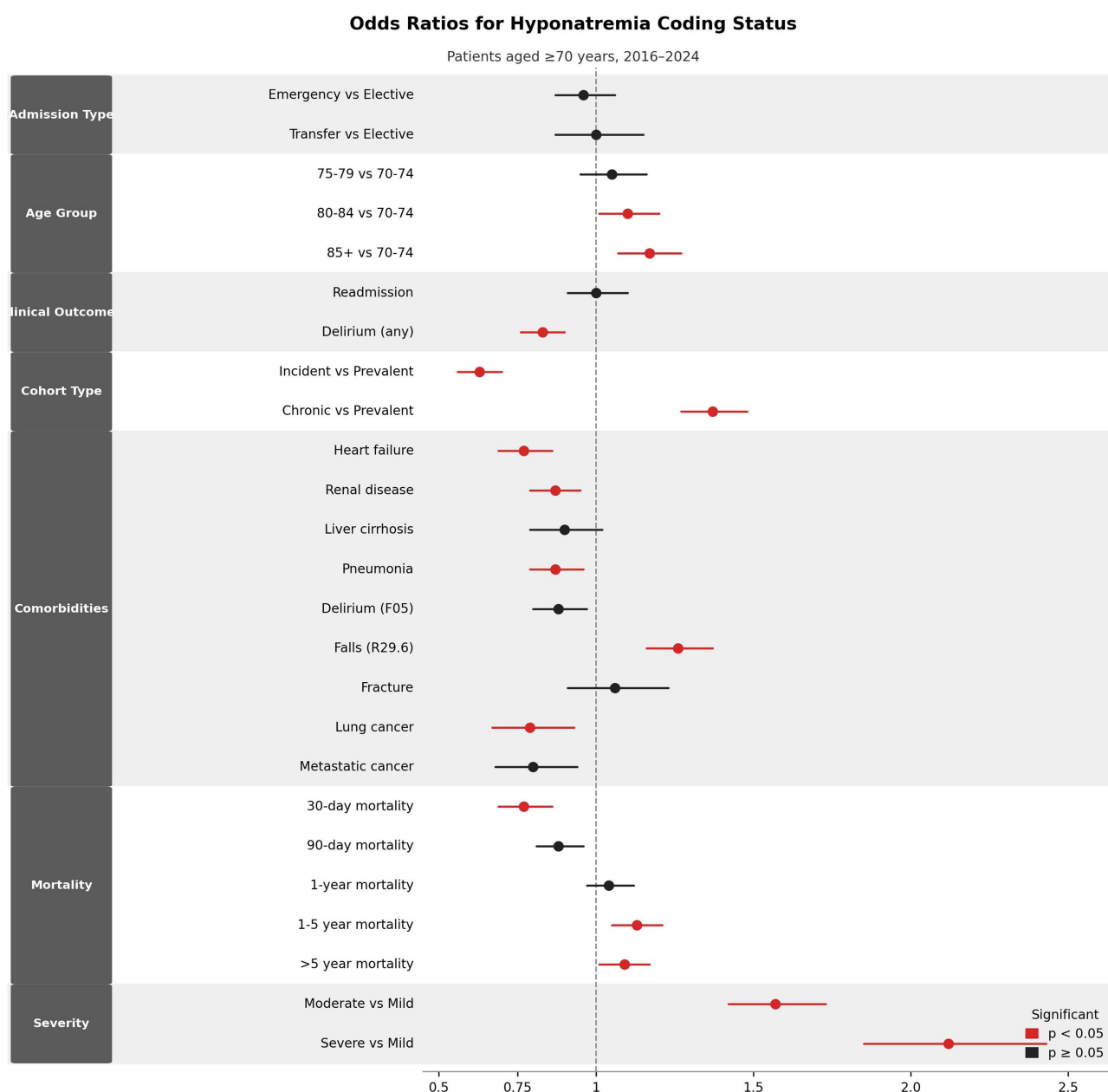


Figure 3 Forest plot of odds ratios for hyponatremia coding status. Values less than 1 (left of the vertical reference line) indicate higher likelihood of being uncoded. Red markers indicate statistically significant associations ($p < 0.05$). The plot demonstrates that incident cases, patients with early mortality, and those with serious comorbidities are significantly more likely to have hyponatremia uncoded.

This shows that coded patients have more severe hyponatremia ($OR = 3.98$ for severe cases). Uncoded patients are more likely to be critically ill with competing diagnoses (higher CMI, heart failure, mortality). Overall, the logistic regression model indicates that hyponatremia is more likely to be coded in patients with more severe biochemical hyponatremia, whereas patients with higher case-mix complexity, heart failure, malignancy and early mortality are paradoxically less likely to have hyponatremia coded. This pattern suggests diagnostic and coding competition in clinically complex, high-risk patients.

Linear Regression Focusing Determinants of Operating Cost

We examined the linear regression focussing determinants of operating costs. The model explains 76.5% of cost variation (Adjusted $R^2 = 0.765$, $F = 4326.75$ $p < 0.001$). Cost-Reducing Factors (Negative Associations):

Table 9 Logistic Regression: Factors Associated with Hyponatremia Coding N = 13,291

Variable	Coefficient	SE	OR	95% CI lower	95% CI upper	p-value
Age (per year)	0.03	0.01	1.03	1.02	1.04	<0.001
Sodium minimum (per mmol/L)	−0.14	0.01	0.87	0.85	0.9	<0.001
Moderate (vs. mild)	1.29	0.1	3.65	3.02	4.39	<0.001
Severe (vs. mild)	1.38	0.18	3.98	2.76	5.71	<0.001
Length of stay (per day)	−0.02	0.01	0.98	0.97	0.99	<0.001
Case Mix Index	−0.14	0.03	0.87	0.82	0.92	<0.001
Fracture	0.19	0.07	1.21	1.05	1.4	0.009
Delirium	−0.22	0.13	0.81	0.63	1.03	0.084
Mortality (1 year)	−0.39	0.07	0.68	0.59	0.78	<0.001
Heart failure	−0.83	0.1	0.44	0.36	0.53	<0.001
Emergency admission	0.21	0.08	1.24	1.05	1.46	0.012
Any target medication	0.19	0.06	1.21	1.08	1.36	0.002

Notes: McFadden Pseudo R^2 = 0.224; AIC = 7970.91.

- Coded Status (Critical Finding): −CHF 2,148, $p < 0.001$. Interpretation: On average, coded cases had 2,148 CHF lower operating costs than uncoded cases, despite having more severe biochemical hyponatremia. This suggests that uncoded patients tend to be more complex and resource-intensive overall, and that coding occurs preferentially in less complex, more manageable cases. This suggests:
 1. Uncoded patients have operating costs that are CHF 2,148 higher
 2. Coding occurs preferentially in less complex cases
 3. Uncoded patients may have higher overall acuity (supported by Model 1: mortality OR = 0.68)
 4. Systematic under-coding in resource-intensive patients
- Emergency Admission: −CHF 2,602, $p < 0.001$. Interpretation: Emergency admissions cost CHF 2,602 less than elective admissions, likely due to shorter procedural interventions and expedited care pathways.
- Age: −CHF 90 per year, $p < 0.001$. Interpretation: Each additional year of age reduces costs by CHF 90, possibly reflecting less aggressive interventions in very elderly patients or survivor bias.
- Lower Sodium: −CHF 149 per mmol/L, $p < 0.001$. Interpretation: In the fully adjusted model, lower minimum sodium values were associated with slightly lower operating costs per case. This counterintuitive association likely reflects differences in clinical pathways and patient selection (eg. more structured management in clearly recognised, coded severe hyponatremia) rather than a causal cost-reducing effect of more severe hyponatremia. (Table 10).

This model showed an adjusted $R^2 = 0.765$ indicating strong explanatory power

Table 11 summarizes this results. Taken together, the regression models should be interpreted as describing adjusted associations that reflect different patient profiles and care pathways for coded versus uncoded hyponatremia, rather than implying that lower sodium levels or coding status are inherently cost-reducing in a causal sense.

Table 10 Linear Regression: Determinants of Operating Costs

Variable	Coefficient (CHF)	SE	p-value
Coded (vs. Uncoded)	−2147.9	352.93	<0.001***
Age (per year)	−89.54	17.2	<0.001***
Sodium minimum (per mmol/L)	−149.35	29.84	<0.001***
Length of stay (per day)	678.08	15.93	<0.001***
Case Mix Index (CMI)	6,626.41	68.26	<0.001***
Delirium	6,453.24	420.49	<0.001***
Fracture	2,012.7	279.73	<0.001***
Mortality (1 year)	1,639.19	235.46	<0.001***
Admission Type			
Emergency admission	−2,602.22	273.12	<0.001***
Medications			
N distinct ATC codes	−63.78	150.5	0.672
Constant	29,060.99	4,162.47	<0.001***

Notes: N = 13,283; Adjusted R^2 = 0.765; $F(10, 13272) = 4,326.75^{***}$.

Table 11 Regression Models: Coding Status and Operating Costs

	Dependent variable		Dependent variable	
	Coded (1=Yes, 0=No)		Operating Costs (CHF)	
	logistic		OLS	
	Coded (Logistic)		Operating Costs (OLS)	
	Model 1		Model 2	
Variable	Coefficient	SE	Coefficient	SE
Age (years)			−2,147.90***	−352.93
Sodium minimum (mmol/L)	−0.03***	−0.005	−89.54***	−17.2
Moderate hyponatremia	−0.13***	−0.01	−149.35***	−29.84
Severe hyponatremia	1.29***	−0.09		
Length of stay (days)	1.38***	−0.19		
Case Mix Index (CMI)	−0.02***	−0.01	678.08***	−15.93
Fracture	−0.14***	−0.03	6,626.41***	−68.26
Delirium	0.19**	−0.07	2,012.70***	−279.73
Mortality (1 year)	−0.22	−0.13	6,453.24***	−420.49
Coded (vs. Uncoded)			1,639.19***	−235.46
Emergency admission	0.21*	−0.08	−2,602.22***	−273.12
Heart failure	−0.83***	−0.1		

(Continued)

Table 11 (Continued).

	Dependent variable		Dependent variable	
Any medication	0.19**	−0.06		
N distinct ATC codes			−63.78	−150.5
Constant	12.96***	−1.91	29,060.99***	(4,162.47)

Notes: Observations 13291, R^2 0.77, Adjusted R^2 0.77, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Present Value of Future Cost

In addition to the bottom-up calculation of the economic burden (approximately 479 MCHF over 9 years), we estimated an average annual incremental burden of about 52.5 MCHF, assuming no major change in the management of ucHn. (To calculate the present value of an annual burden of 52.5 MCHF over the next 9 years, we applied a discount rate of 5% in line with international standards for economic evaluations. The interest rate would be 5% following international standards for discounting.

Then we have:

$$PV = \sum_{t=1}^n \frac{Ct}{(1+r)^t}$$

- PV: Present Value)
- Ct: Cost in a year t
- r: Discounting rate (0.05)
- n: Number of years

$$PV = 52.5 \times \left(\frac{1}{1.05^1} + \frac{1}{1.05^2} + \dots + \frac{1}{1.05^9} \right) = PV \approx 52.5 \times 7.1078 = 373.55 \text{ MCHF}$$

Assuming that the current situation persists and ucHn remains at this high level, the present value of approximately 373.55 MCHF reflects the amount that would need to be set aside today to cover the projected future costs.

Intangible Cost

Intangible cost like loss of life quality, grade of pain, decrease of autonomy, loss of cognitive control have not been measured nor were any data available.

Indirect Cost

Have not been calculated by analysis of the secondary inputs and affording for the family and the next partners helping and supporting the ucHN patient while interrupting their working process and losing money. This additional effort and calculable effort, such as the waiting time, transport cost, were not accountable.

Ethics

Due to the retrospective manner, the underlying COI has no ethical problems.

Discussion

This study provides new insights into the true epidemiological, societal and economic scope of hyponatremia in geriatric inpatients. By integrating previously uncoded cases (ucHn), it reveals that the actual prevalence and cost burden of the condition are substantially higher than suggested by coded data alone. Among 72,730 patients aged ≥ 70 years, the coded prevalence (cHn) was 2.8%, while laboratory data identified an additional 15.9% uncoded cases, resulting in a true prevalence of approximately 18.7% – about six times higher than administrative records indicate.³³ These results may be a consequence of ucHn as a symptom of complexity and of multimедication (it can be dependent to the underlying treatment with diuretics and SSRI delivering different epidemiologic data).³⁴ And it is obvious: ucHn and cHn belong to two different patient groups with different diseases and medications.

A notable epidemiologic observation is the gender shift. While earlier literature reported higher rates among women, this analysis found a predominance of men in the uncoded cases, particularly in the 70–79 age group, whereas patients >85 years were more frequently coded. These findings may reflect gender-specific differences in recognition patterns and admission subgroups.

In terms of severity, mild hyponatremia accounted for 76.8% of all cases. This subtype predominated in uncoded patients compared to coded cases, underscoring systematic under-detection of mild electrolyte disturbances. Given that even mild chronic hyponatremia is associated with falls, cognitive decline, and increased mortality, the magnitude of under-recording shown here reflects a substantial clinical and economic blind spot in geriatric care.

From an economic perspective, uncoded hyponatremia is associated with a substantial incremental burden in terms of complications, prolonged length of stay, higher mortality and increased costs, particularly in frail, multimorbid elderly patients. From a broader societal perspective, this translates into loss of independence, functional decline and long-term care needs.

Cumulative financial modeling by bottom up analysis revealed a total incremental cost of ≈ 355 to 479 MCHF for the years 2016–2024, driven by prolonged LOS, missed coding revenue, complications, and an attribution driven mortality calculation (Figure 3). The PSA confirmed the total incremental cost as a robust result, which under real conditions will probably be much higher.

This study shows that uncoded hyponatremia (ucHn) is strongly associated with a substantially higher clinical and economic burden compared with both coded hyponatremia (cHn) and normonatremia. ucHn patients experience more complications (fractures, delirium), longer hospital stays, higher cumulative mortality and markedly increased costs per case. The question remains: does the implementation of automated laboratory-based coding prevent not only hospital losses but also these social impacts?

Limitations

The study was of retrospective manner limiting the actuality of the used data for calculation. This study was conducted only in one tertiary hospital, which makes it difficult to generalize the results to other hospitals even when this hospital is one of the biggest in Switzerland. The age group focused on >70 years of age makes it impossible to generalize the results on younger patients. We had not the possibility to measure intangible costs. Delirium cases are rare due to an undercoding and underdocumentation of delirant states in the period of the 9 years leading to much lower cost as awaited in this sector. Despite extensive multivariable adjustment for age, minimum sodium, severity category, case-mix index, comorbidities, complications, length of stay, admission type and one-year mortality, residual confounding cannot be excluded, particularly with respect to frailty and explicit palliative status, which were not systematically coded in the routine data. Our findings should therefore be interpreted as adjusted associations rather than proven causal effects.

Second, our estimates of mortality-related costs rely on predefined attribution scenarios (100%, 75%, 50% of end-of-life costs ascribed to hyponatremia). These shares reflect modelling assumptions used in the probabilistic sensitivity analysis to explore the plausible range of hyponatremia-attributable costs in multimorbid elderly inpatients and are not intended as precise causal fractions. Nonetheless, the excess mortality observed in ucHn patients across all time horizons indicates that hyponatremia is an important marker of poor prognosis and a relevant driver of downstream resource use.

Third, the large sample size in our cohort means that many comparisons yield very small p-values. While this underlines the statistical robustness of the associations, it also implies that statistical significance alone is not a sufficient indicator of importance. We therefore focus our interpretation on the magnitude and clinical relevance of the observed effect sizes, such as additional length of stay, absolute differences in fracture and delirium rates, and incremental costs per case.

Finally, some regression findings, such as the association between lower minimum sodium and slightly lower operating costs, may appear counterintuitive at first sight. We interpret these adjusted associations as reflections of different patient profiles and care pathways in coded versus uncoded hyponatremia: coded cases tend to represent clearly recognized and actively managed episodes, whereas uncoded cases cluster in highly complex, multimorbid patients with competing diagnoses, higher case-mix and more complications. These models are therefore best viewed as hypothesis-

generating, highlighting systematic under-coding in the most resource-intensive patients, rather than as proof of a cost-reducing effect of more severe hyponatremia.

Future Recommendation

A second evaluation of this study on hand with a control group would help to objectivize the results. An additional calculation of indirect costs on the basis of a conjoint analysis in combination with these data is actually in planning with the Forschungsrat Aarau (Number 1410.000.288) to complete the scientific approach to ucHn and the patients.

Conclusion

In this large retrospective cohort of elderly inpatients, uncoded hyponatremia (ucHn) was common and associated with a markedly higher clinical and economic burden than both coded hyponatremia (cHn) and normonatremia. ucHn cases had more complications (fractures, delirium), longer hospital stays, higher cumulative mortality and substantially increased costs per case. Our findings suggest that hyponatremia is frequently under-recognised and under-coded precisely in the most complex, high-risk patients, thereby creating a hidden burden that is not adequately captured in administrative data or in current cost-of-illness estimates. Improving detection, documentation and structured management of hyponatremia in frail, multimorbid elderly inpatients could help reduce preventable complications, align reimbursement with true case complexity and mitigate the social and economic impact of this common electrolyte disturbance.

This study quantifies, for the first time, the combined social and economic burden of uncoded hyponatremia in Swiss hospital care. The true prevalence of hyponatremia exceeded administrative estimates by approximately a factor of six. From a clinical perspective, the high proportion of uncoded mild hyponatremia is particularly critical, because even mild ucHn is associated with falls, fractures and increased mortality; in our cohort, virtually every ucHn patient experienced at least one adverse outcome such as loss of mobility, autonomy, cognitive function or survival (Table 6). Thus, failure to detect, document and evaluate these cases reflects not only a coding issue but also a potential quality-of-care gap with substantial social implications.

While previous top-down approaches estimated average costs of roughly 3,000–4,000 CHF per hyponatremia case, our detailed bottom-up analysis suggests total incremental costs of up to about 41,000 CHF per ucHn case. The resulting difference of approximately 28,000–38,000 CHF per case in a hybrid calculation framework underscores how much conventional top-down estimates may underestimate the true economic burden and highlights opportunities for richer information and tighter managerial control (Table 12).

Table 12 Comparison of Top-Down vs. Bottom-Up Cost-Per-Case Frameworks in Health-Economic Analysis

Frame-work Type	Mean -Cost per Case (CHF)	Primary Data Source/ Method	Cost Elements Included	Strengths/Limitations	Applicability to Hyponatremia Study
Top-Down Approach	3000–4000	Aggregated administrative and billing data; national hospital or insurance cost averages	Direct inpatient medical costs (e.g., diagnostics, medication, LOS extension)	Efficient for macro-level comparisons; less granular. May underestimate disease- specific burden due to coding limitations.	Baseline estimates; used in previous US and EU meta-analyses for hyponatremia.
Bottom-Up Approach (COI Model)	≈41379	Patient-level Swiss hospital data (2016–2024) with DRG, LOS, laboratory, and outcome records	Direct + indirect costs (LOS extension, medication, missed coding revenues, rehospitalizations fractures, delirium, mortality, institutional -care)	Fully captures real resource use and economic losses. Requires detailed-local data; time-intensive.	Quantifies hidden burden of uncoded hyponatremia (ucHn) and system- wide under-coding impact.
Integrated Top-Down + Bottom- Up (Hybrid)	≈27,155 –37,379 (estimated)	Combines national reference costs with case-level adjustments for LOS and complications	Direct medical + selected post- acute costs	Balances generalizability and specificity. Reduces data noise but retains- causal under-coding links.	Recommended for policy extrapolation and international comparison across systems.

Note: Values in 2024 CHF. Top-Down costs reflect published U.S./EU benchmarks (≈CHF 3–4k per case); Bottom-up values derived from Swiss COI Analysis for uncoded Hyponatremia hyponatremia (ucHn). Hybrid framework shown for comparative reference.
Abbreviations: COI, Cost of Illness; DRG, Diagnosis-Related Group; LOS, Length of Stay.

Improving diagnostic coding accuracy, systematic electrolyte screening and structured evaluation of hyponatremia could therefore generate medical, social and economic benefits at scale within geriatric hospital systems.

Acknowledgments

Throughout the planning, execution, analysis, and completion of this master's thesis, we received exceptional support from the scientific team in Aarau and invaluable guidance from the University UPF BSM in Barcelona. We are deeply grateful for all the encouragement and assistance that has been given.

Disclosure

The authors report no conflicts of interest in this work.

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