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# Implementation of Activity-Based Funding and Patient Trajectory Managers' contributions to financial indicators and care in a Swiss General Internal Medicine Department: a retrospective study

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## Summary

BACKGROUND: In 2012, Switzerland introduced a new activity-based funding system (SwissDRG). In 2014, Geneva University Hospitals also introduced a new staff role, Patient Trajectory Manager (PTM), aimed at optimising patient care trajectories, hospital length of stay (LOS) and clinical documentation. The objective of the present study was to analyse the impact of the SwissDRG on quality and efficiency of care in our division. We also analysed the impact of the implementation of Patient Trajectory Managers on efficiency.

METHODS: We analysed 59,621 hospitalisations between 2007 and 2019 using statistical description with an ARIMA model, complemented by interrupted time-series analysis based on SARIMA intervention models. The primary outcome was LOS; secondary outcomes included average length of stay (ALOS), Cost Weight, discharge destination, difference vs theoretical ALOS, readmissions and mortality.

RESULTS: Following SwissDRG implementation, median LOS decreased from 10 days (2007–2011) to 8 days (2012–2019; p <0.001), with a higher proportion of patients discharged home (70.2% vs 75.4%, p <0.001). Interrupted time-series analyses confirmed a significant immediate reduction in LOS at the time of SwissDRG introduction, followed by a sustained downward trend. No significant effects were observed on 18-day readmissions or in-hospital mortality. After the introduction of PTMs, LOS continued to decrease and remained below predicted trajectories derived from pre-PTM trends, but interrupted time-series analyses did not identify an additional significant abrupt level reduction. However, significant post-intervention slope changes were observed for LOS-related efficiency indicators, indicating a sustained monthly reduction over time rather than an immediate effect. The period after PTM implementation was also associated with a reduced gap between observed and theoretical DRG LOS and fewer LOS upper-outliers, without adverse effects on readmissions or mortality.

CONCLUSION: There was a significant decrease in LOS across the three successive periods of observation. The introduction of activity-based funding through SwissDRG was associated with a major and immediate significant reduction in hospital LOS. However, subsequent organisational interventions through the implementation of Patient Trajectory Managers did not produce an additional causal level significant reduction in LOS but was associated with sustained improvements in efficiency-related trends, optimisation of DRG-related performance and stabilisation of care processes over time, without compromising patient outcomes.

## Introduction

Among the many different ways of financing hospital care, over the last 30 years activity-based funding (ABF) has become the norm in many Western countries (the USA in 1983; Australia in 1992; Finland, Sweden and Norway in 1995; France in 1996, the United Kingdom in 2003; Germany and The Netherlands in 2005; and Switzerland in 2012) [1]. It has replaced other hospital financing

methods, such as fixed overall budgets or budgets based on actual costs or daily indemnities [2]. One of the activity-based funding models is based on a Prospective Payment System that relies on identifying different homogeneous groups of patients by *Diagnosis-Related Group*s (DRGs) with hospitals receiving a fixed predetermined payment per case in each DRG category [3]. This type of system was initially aimed at reducing overall healthcare expenditure (explaining why it is so widespread), making hospital financing more transparent and equitable, improving efficiency and reducing the financial incentives linked to payments for medical acts or daily indemnities [2]. Activity-based funding appears to reduce both hospital length of stay (LOS) [4] and costs [5], with a transfer of cost to rehabilitation or ambulatory structures [6], without any impact on mortality, readmissions or the amount of care provided [7]. In the USA, activity-based funding has been associated with increased severity of the illnesses for which patients are hospitalised, and a greater number of transfers to medium-term care institutions [7]. In Switzerland and Germany, no clear evidence was found that activity-based funding affected the quality of care, the number of cases, the medical profession, patient satisfaction or reimbursements per case. However, activity-based funding did seem to have a positive impact on hospital LOS and, perhaps, on overall hospitalisation costs [8]. However, global costs appear relatively unaffected, as activity-based funding seemed to generate a transfer in invoicing (and thus costs) downstream towards institutions involved in rehabilitation and outpatient care [9]. Even if DRG could reduce hospital costs per patient, it is not clear that it reduces the costs of total management of patients [10]. DRG-based and activity-based funding payment models have significant effects on healthcare costs and patient outcomes: significant reductions in total hospital costs [11] and LOS [12], but variable effects on quality of care [12, 13].

Switzerland adopted the DRG-based and activity-based funding system in 2012, with payments to hospitals changing from an average daily rate for each day hospitalised, to being linked to a rate per case type based on the different SwissDRGs [14]. Switzerland's DRGs comprise a defined number of patient groups who share similar diagnoses and undergo similar procedures distinguished according to their clinical components (types of interventions and their associated treatments) and corresponding resource use. Each DRG is assigned a theoretical average LOS (ALOS) with predefined upper and lower boundaries. When a patient's LOS exceeds the theoretical upper boundary, their stay is termed an upper-outlier. Each DRG also has a calculated cost weight (CW), which represents the amount of care resources that need to be attributed to each group of pathologies [15]. This CW is constant when the LOS is between the lower and upper LOS boundaries, but it varies when outside them. The CW is calculated to reflect the burden of care compared to the SwissDRG's theoretical ALOS. The CW is then used to calculate the cost of the hospital stay by multiplying it by the hospital point price. Thus, hospital stays with costs that are most likely to be covered at 100% are those that do not exceed the theoretical ALOS. This type of hospital financing clearly incites institutions to manage patients' LOS and produce exhaustive clinical documentation.

There are very many actions that hospitals can undertake to improve the average length of stay: clinical pathways, case management, care coordination, discharge planning and multidisciplinary care teams [16]. In Germany, Switzerland's major inspiration in developing its SwissDRG system, certain hospitals have successfully introduced length-of-stay-orientated case managers. Their objectives include avoiding unjustified procedures, ensuring optimal LOS and effectively managing discharge. These case managers pre-code the cases to obtain a pre-DRG in order to best manage the trajectory using the theoretical ALOS of the DRG [17].

In April 2014, the General Internal Medicine (GIM) Division of HUG (Geneva University Hospitals) introduced a new role, Patient Trajectory Manager (PTM), to help reduce LOS, improve clinical documentation and optimise patient ICD-10 coding, following the German experience [17]. The principal aim was to anticipate hospital discharge and to optimise the mean LOS, getting it as close as possible to the theoretical ALOS. To do this, the PTM assigns a "pre-code" to each patient at admission (code of known diagnosis at admission using ICD-10) with a provisional DRG. Thus, a theoretical ALOS is allocated determining a provisional discharge date. In addition, PTMs coordinate the patient's care trajectory, ensuring the best possible coordination and collaboration between the different healthcare professionals within the GIM Division. Other PTM tasks include improving the quality of clinical documentation, preparing discharge documentation and optimising patient DRG coding via the exhaustive recording of all medical activities. At the end of 2019, an additional five PTMs were employed. Between 2012 and 2019, the GIM Division comprised 160 acute beds on 10 wards. Its staff included 35 resident doctors (providing 24/7 care), 11 senior residents, 8 attending physicians and the head of division.

In the present article, we describe our analysis and measurement of the impact of the SwissDRG hospital tariff structure on our department between 2007 and 2019, as well as the additional financial and qualitative impact of the 2014 introduction of the PTM role.

## Methods

Our analysis retrospectively included all patient stays in the GIM Division between 1 January 2007 and 31 December 2019.

*Data and variables:* All data for the study were collected from the HUG Enterprise Data Warehouse (EDW). The electronic medical record system provided clinical data while the accounting costing system provided financial data. Detailed admission data were gathered from hospital discharge summaries comprising admission and discharge dates, admission source, discharge destination and length of stay (LOS).

We analysed our primary outcome (measured LOS of the entire hospital stay) during each year as well as secondary outcomes which included: the number of hospitalisations, occupancy rate, mean patient age, nursing workload score (available since 2010), patient destination post-acute care stay (discharge home or transfer to a rehabilitation unit; information available since 2009), 18-day readmission rate (available since 2012), intra-hospital mortality rate, 3-month out-of-hospital mortality rate (available since 2010), quality of discharge documentation (score), time required to complete patient coding (reliable since 2012), difference between actual LOS and theoretical average ALOS (difLOS-ALOS), percentage of upper-outliers, cost weight (the case mix index [CMI]) and the Charlson Comorbidity Index approximated using the R *comorbidity* package on the ICD diagnosis list.

We performed analyses to evaluate the impact of the 2012 introduction of the SwissDRG tariff structure on the GIM Division and the supplementary impact of the Patient Trajectory Managers employed by the GIM Division from 2014.

We described three different periods – no DRG/PTM (2007 to 2012), only DRG (March 2012 to 2014), DRG and PTM (April 2014 to 2019) – and compared median and proportion of outcomes in the three periods.

To describe the evolution, we compared first median/proportion outcomes in the three periods. Categorical variables in different groups were compared using the Fisher or chi-squared tests, and quantitative data were compared using the Mann–Whitney–Wilcoxon or Student's t-tests.

We performed a monthly aggregation for time-series analysis with mean/proportion calculations and we used a time-series ARIMA model to evaluate the evolution of LOS and difLOS-ALOS, if no change had occurred in the process (forecast trained on DRG period data), compared to real data [18]. Seasonality in monthly indicators was assessed using the Osborn-Chui-Smith-Birchenhall (OCSB) test for seasonal unit roots. For all outcomes, the test indicated that no seasonal differencing was required, suggesting the absence of a deterministic seasonal trend.

To test the implementation of DRGs then the implementation of Patient Trajectory Managers, we used a full mathematical formulation of seasonal autoregressive integrated moving average (SARIMA). Temporal trends and seasonality are modelled with SARIMA, but other variables are not analysed as confounders. Formal causal inference relied on interrupted time-series (ITS) analyses using SARIMA intervention models, following the Box–Tiao framework [19]. Monthly aggregated indicators were modelled as stochastic processes incorporating autoregressive, moving-average and seasonal components. For outcomes available across all periods, models included two sequential interventions: SwissDRG (January 2012) and PTM (January 2014). For DRG-defined indicators, models were restricted to the periods "only DRG" and "DRG and PTM" and included only the PTM intervention. Each intervention was modelled using two deterministic functions: (i) a step function representing an immediate level change, and (ii) a ramp function representing a change in post-intervention slope. Models including level change only, slope change only and combined level and slope change were estimated. Model selection was based on the Akaike Information Criterion (AIC). Statistical inference on intervention parameters used model-based standard errors, and cumulative effects at 6, 12 and 24 months were estimated using the delta method. This approach allows isolation of intervention-related changes while explicitly accounting for underlying trends and seasonality.

All simple pre–post comparisons are reported for descriptive purposes only. Causal inference regarding the impact of SwissDRG and PTM implementation relies exclusively on time-series analyses explicitly accounting for serial correlation and seasonality.

Statistical analyses were performed with R software, version 4.0.0 (https://cran.r-project.org/).

The protocol was submitted to the Geneva Research Ethics Commission which qualified it as a quality project.

## Results

The overall cohort of patients treated at HUG's GIM Division between 2007 and 2019 involved 59,621 hospital stays.

### Description of pre-DRG period (2007–2011) and post-DRG period (2012–2019)

Following our analysis of the two groups (table 1), pre- and post-introduction of the DRG tariff structure, we noted that the measured median LOS during the post-DRG period (2012–2019) was significantly shorter than in the pre-DRG period (2007–2011): 8 [IQR: 5–13] days vs 10 [IRQ: 6–16] days (p <0.001); intra-hospital mortality also diminished significantly (4% vs 4.8%, p <0.001).

**Table 1:** Results of the comparative analysis between the two subgroups before and after the introduction of the SwissDRG tariff structure.

| | Pre-DRG period: 2007–2011 (n = 38,854) | Post-DRG period: 2012–2019 (n = 20,767) | p |
|---|---|---|---|
| Age in years, median [IQR] | 69 [54;79] | 68 [54;79] | 0.064 |
| Female sex, n (%) | 17,362 (44.7 %) | 9509 (45.8 %) | 0.01 |
| Charlson comorbidity index, mean, median [IQR] | 4.7, 4 [3;6] | 4.41, 4 [2;6] | <0.001 |
| Nursing workload score, median [IQR] (available since 2010) | 2086 [1045;4222] | 2081 [1094;4040] | 0.93 |
| Measured LOS in days, median [IQR] | 10 [6;16] | 8 [5;13] | <0.001 |
| Intra-hospital mortality, % | 4.8% | 4% | <0.001 |
| Discharge home/transfer to rehabilitation (available since 2009), %/% | 70.2%/29.8% | 75.4%/24.6% | <0.001 |
| Time required for signing-off on discharge documentation in days, median [IQR] | 13 [8;22] | 10 [6;15] | <0.001 |

IQR:interquartile range; LOS: length of stay.

Patients were discharged to their homes more often during the post-DRG period than during the pre-DRG period: 75.4% vs 70.2%, respectively, p <0.001. Although continually shortening from 2009 onwards, the median time taken to sign off on patient discharge documentation was shorter during the post-DRG period than during the pre-DRG period, 10 vs 13 days after discharge, respectively, p <0.001.

### Description of the periods before (2012–2013, only DRG period) vs after the introduction of Patient Trajectory Managers (2014–2019, PTM period)

In the PTM period, we note that there was a significant improvement in the majority of median outcomes, with the exception of the 3-month out-of-hospital mortality rate (non-significant difference), the 18-day readmission rate (non-significant difference) and the invoiced and theoretical CMIs (better before Patient Trajectory Managers introduced) (table 2).

**Table 2:** Results of the comparative analysis between the two subgroups before (2012–2013) vs after (2014–2019) the introduction of Patient Trajectory Managers (PTM).

| | **Before PTM: 2012–2013 (n = 11,902)** | **After PTM: 2014–2019 (n = 26,784)** | **p** |
|---|---|---|---|
| LOS in days, median [IQR] | 9 [5;15] | 8 [5;13] | <0.001 |
| Female sex, n (%) | 5417 (45.5%) | 11855 (44.3%) | 0.02 |
| Charlson comorbidity index, mean, median [IQR] | 4.4, 4 [2;6] | 4.4, 4 [2;6] | 0.2 |
| Difference vs mean theoretical ALOS [LOS-ALOS] in days, median [IQR] | 0.5 [-2.6;4.9] | 0.2 [-2.4;4.1] | <0.001 |
| Inappropriate hospital stay in days, median [IQR] | 0.5 [0;4.9] | 0.2 [0;4.1] | <0.001 |
| 18-day readmission rate, % | 3.25% | 3.5% | 0.24 |
| Intra-hospital mortality rate, % | 4.45% | 3.8% | 0.005 |
| 3-month out-of-hospital mortality rate, % | 0.13% | 0.090% | 0.17 |
| Discharge home/transfer to rehabilitation, %/% | 74.1%/25.9% | 76.2%/23.8% | <0.001 |
| Upper-outliers, % | 14.8% | 13.3% | <0.001 |
| Invoiced CMI, median [IQR] | 1 [0.7;1.7] | 0.9 [0.7;1.4] | <0.001 |
| Theoretical CMI, median [IQR] | 1 [0.7;1.6] | 0.9 [0.7;1.4] | <0.001 |
| Quality of discharge documentation score, mean | 92.8 | 97.3 | <0.001 |
| Time required for signing off on discharge documentation in days, median [IQR] | 9 [6;14] | 10 [6;15] | <0.001 |
| Time required for coding in days, median [IQR] | 48 [32;63] | 25 [14;42] | <0.001 |

ALOS: average length of stay; CMI: case-mix index; IQR: interquartile range; LOS: length of stay.

The evolution of the main outcomes over the three periods and the slopes of evolution are shown in figure 1, allowing the decrease in LOS and difLOS-ALOS to be visualised.

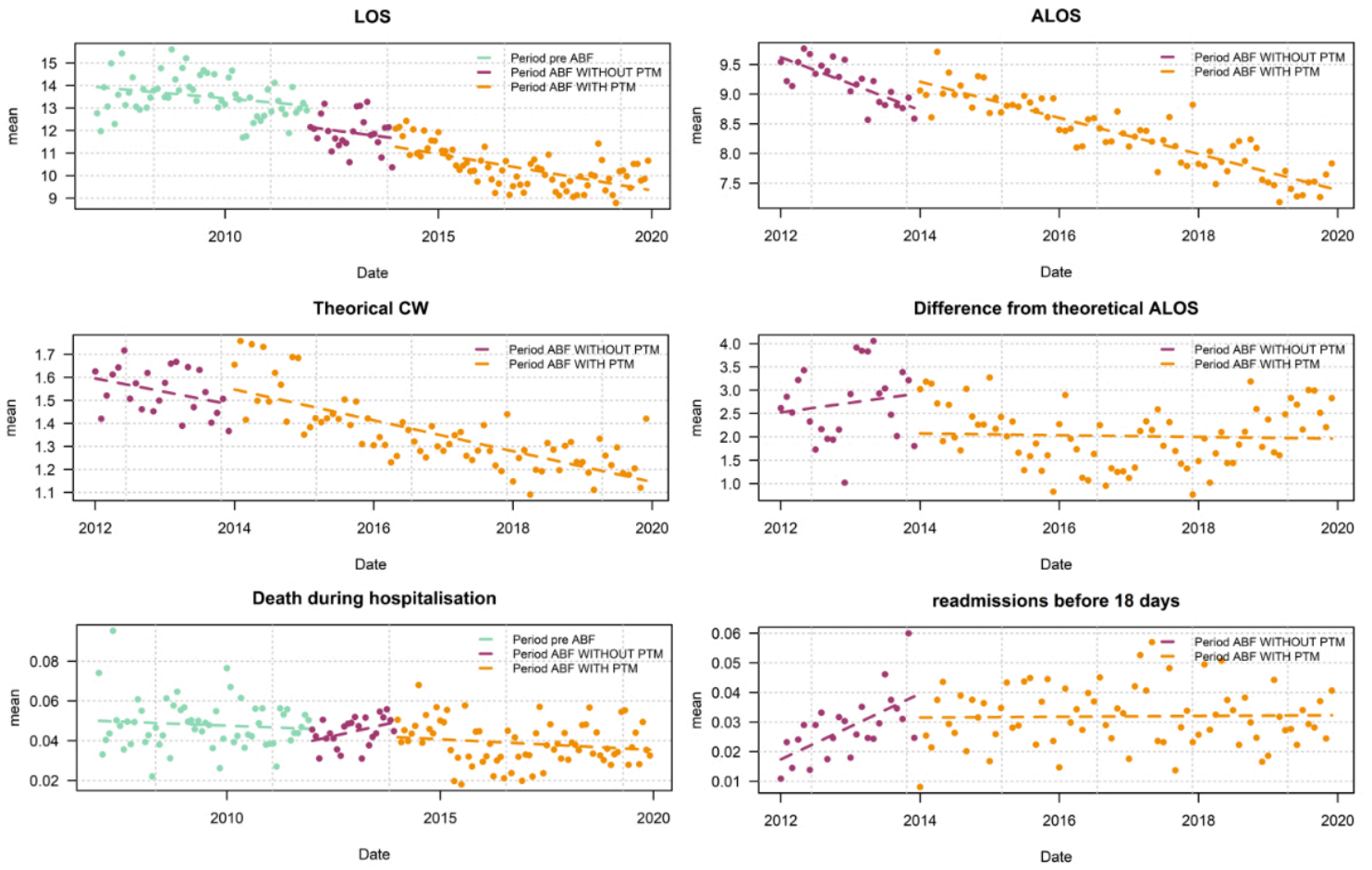



**Figure 1:** Time trends of main outcomes (length of stay, ALOS, theoretical CW, difference vs theoretical ALOS, deaths during hospitalisation, readmissions) during the three periods (Before activity-based funding [2007–2011], After activity-based funding without PTM [2012–2014] and After activity-based funding with PTM [2014–2019]). Points represent monthly mean values. Linear trend lines are shown for visual guidance only. Mean LOS, ALOS and Difference vs theoretical ALOS are in days. Number of deaths and readmissions are expressed as a rate.

To integrate time as a confounding factor, we used the ARIMA model and predict evolution of outcomes during the PTM period, trained on data of the PRG-pre-PTM period (figure 2 and table 3).

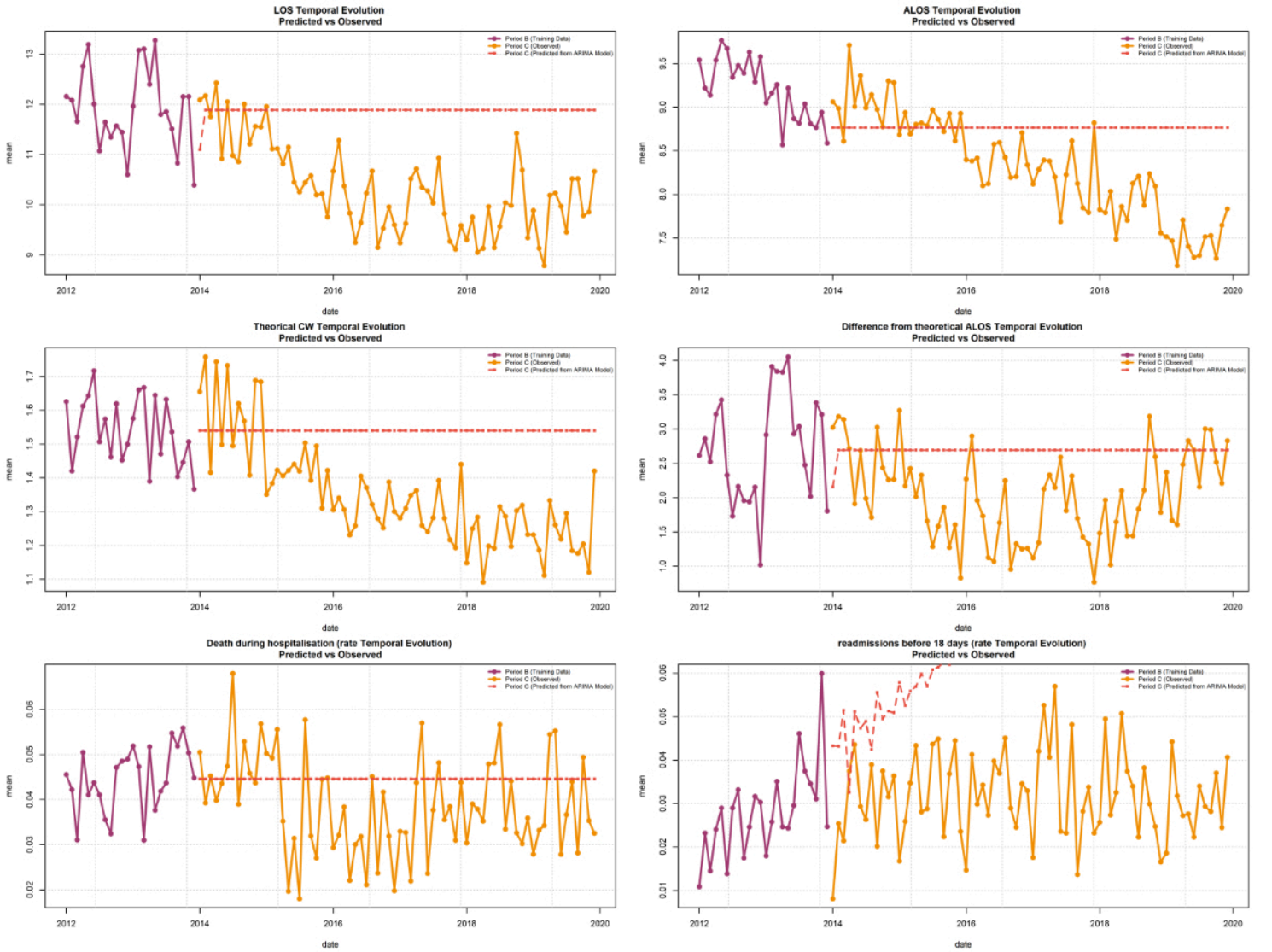



**Figure 2:** Evolution of main outcomes (length of stay, ALOS, theoretical CW, difference vs theoretical ALOS, deaths during hos-pitalisation and readmissions) with ARIMA model predictions during the period with PTM, compared to observed data. Mean LOS, ALOS and Difference vs theoretical ALOS are in days. Number of deaths and readmissions are expressed as a rate.

Comparison of predicted and observed data show a significant difference in LOS (-1.55 days, p <0.01) and difLOS-ALOS (-0.67 days, p <0.001). These differences should be interpreted cautiously, as forecast-based comparisons do not constitute causal inference. Across the study period (2007–2019), the mean hospital LOS showed a marked downward trend. Importantly, these findings indicate that Patient Trajectory Managers could contribute to efficiency gains through progressive optimisation rather than abrupt discharge acceleration.

**Table 3:** Data of ARIMA models for the main outcomes. The predict model is trained on pre-PTM data and compared to the ob-served data during the period with PTM.

| Variable | Model_Order | AIC | MAE | RMSE | MAPE | Observed mean post-PTM | Predict mean post-PTM | Observed-predict difference |
|---|---|---|---|---|---|---|---|---|
| Length of stay | ARIMA0,0,1 | 57.13 | 1.61 | 1.79 | 16.28 | 10.33 days | 11.88 days | 1.55 |
| Average length of stay | ARIMA0,1,1 | 7.35 | 0.60 | 0.74 | 7.57 | 8.31 days | 8.77 days | 0.46 |
| Theoretical cost weight | ARIMA0,0,0 | -39.32 | 0.22 | 0.24 | 17.30 | 1.35 | 1.54 | 0.19 |
| LOS-ALOS | ARIMA0,0,1 | 54.20 | 0.79 | 0.93 | 53.67 | 2.02 days | 2.69 days | 0.67 |
| Deaths | ARIMA0,0,0 | -165.74 | 0.01 | 0.01 | 33.08 | 4% | 4% | 0.01 |
| Readmissions | ARIMA3,1,0 | -149.80 | 0.05 | 0.05 | 174.86 | 3% | 8% | 0.05 |

ALOS: average length of stay; LOS: length of stay

The interrupted time-series analysis demonstrated that the introduction of SwissDRG in January 2012 was associated with a significant immediate and sustained reduction in LOS (figure 3; table 4).

The joint Wald test for SwissDRG step and slope parameters was highly significant ($p < 0.001$), indicating a robust global intervention effect. Following the introduction of Patient Trajectory Managers in January 2014, no significant immediate level change in LOS was observed (table 4). However, ITS-SARIMA models identified a negative post-intervention slope, corresponding to a gradual and sustained monthly reduction in LOS over time (figures 3 and 4).

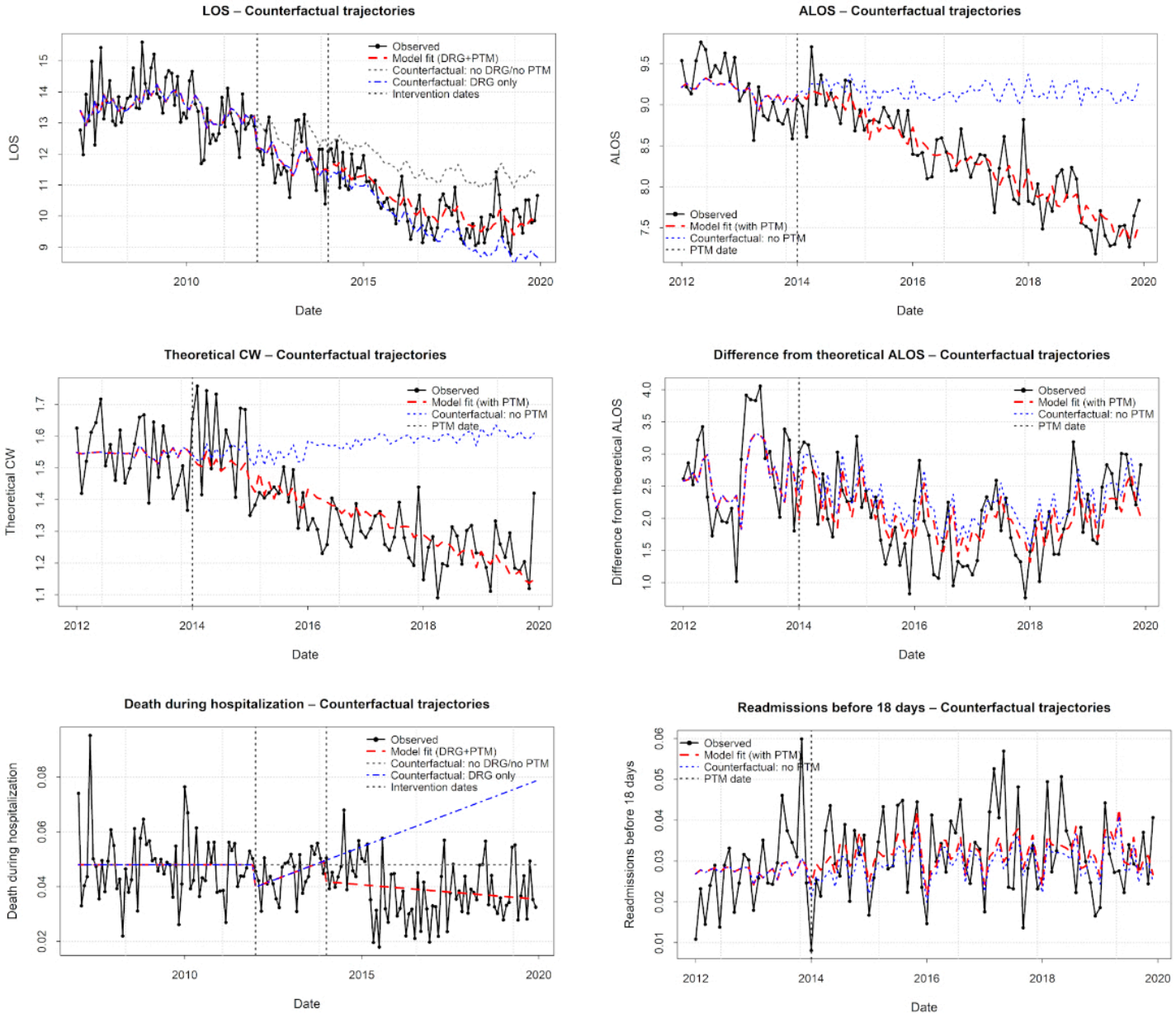



**Figure 3:** Evolution of main outcomes (length of stay, ALOS, theoretical CW, difference vs theoretical ALOS, deaths during hospitalisation, readmissions) using the ITS-SARIMA model. For outcomes available across all periods, models included two sequential interventions: SwissDRG (January 2012) and PTM (January 2014). For DRG-defined indicators, models were restricted to periods B and C and included only the PTM intervention. The 'no DRG/no PTM' curve (grey) illustrates the counterfactual without interventions; the 'DRG only' curve (blue) illustrates the counterfactual without PTM; the red curve corresponds to the adjustment of the complete model. Mean LOS, ALOS and Difference vs theorical ALOS are in days. Number of deaths and readmissions are expressed as a rate.

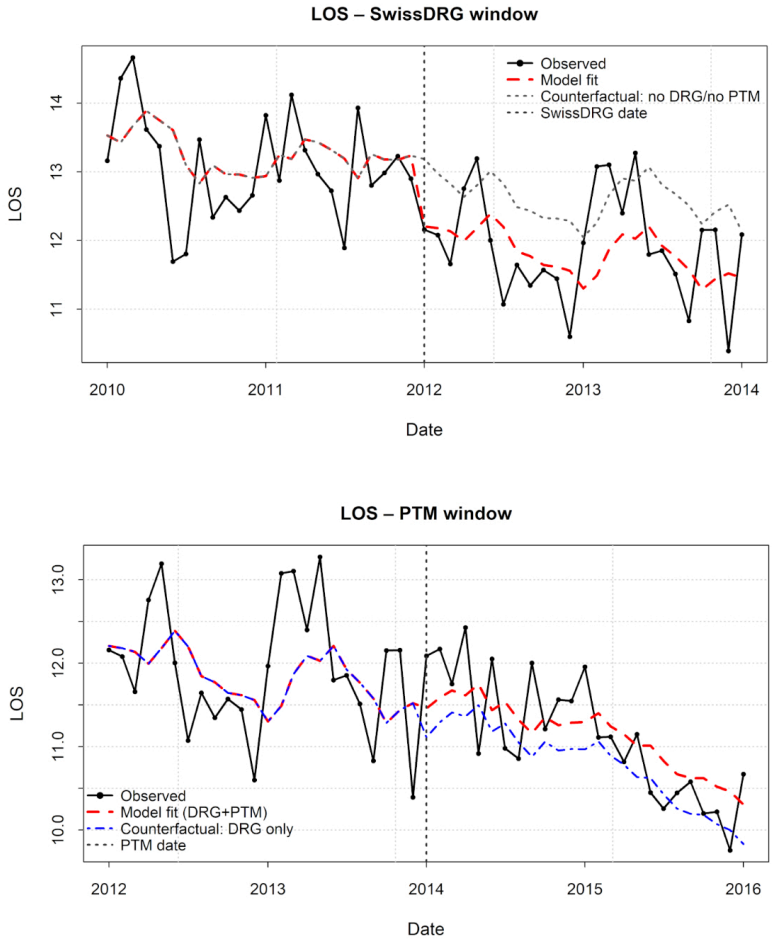



**Figure 4:** FOCUS on ITS-SARIMA for LOS. a) Window centred on the introduction of SwissDRG (January 2012): comparison of observed vs counterfactual without DRG. b) Window focused on the introduction of Patient Trajectory Managers (January 2014): comparison of observed vs counterfactual 'DRG only' (without Patient Trajectory Managers). Mean LOS is in days.

This pattern resulted in clinically meaningful cumulative reductions, although cumulative effects at 12 and 24 months did not reach statistical significance for LOS alone (table 4). For DRG-defined outcomes (ALOS, theoretical CW and difference vs theoretical ALOS), analysed from the pre-PTM period onwards only, PTM implementation was associated with negative slope changes, only significant for ALOS and CW (figure 3; table 4).

Cumulative effects at 12 and 24 months were substantial and statistically significant for ALOS and theoretical CW (table 4). Neither in-hospital mortality nor 18-day readmission rates exhibited significant level or slope changes following either SwissDRG or PTM implementation (figure 3).

**Table 4:** Immediate (step) and trend (slope) effects of SwissDRG and PTM implementation. Interrupted time-series analyses were conducted using SARIMA intervention models (Box–Tiao framework). For outcomes not defined prior to SwissDRG implementation, models were restricted to post-DRG periods (PTM evaluation only). Cumulative effects of PTM implementation at 12 and 24 months were calculated. Cumulative effects were estimated using the delta method and reflect gradual post-intervention changes.

| Outcome | Model scope | DRG step | DRG slope | DRG joint_p | PTM step | PTM slope | PTM joint p | PTM Cum12 | PTM Cum24 | Resid Ljung Box p | Resid ADF p | AIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length of stay | A+B+C (DRG+PTM) | -0.92 [-1.95, 0.10] | -0.06 [-0.13, 0.01] | <0.001 | 0.32 [-0.77, 1.41] | 0.03 [-0.04, 0.10] | 0.696 | 2.75 [-3.60, 9.09] | 9.67 [-12.96, 32.29] | 0.097 | 0.01 | 354.2 |
| Average length of stay | B+C (PTM only) | NA | NA | NA | -0.00 [-0.18, 0.18] | -0.02 [-0.03, -0.02] | <0.001 | -1.90 [-2.08, -1.71] | -7.30 [-8.16, -6.45] | 0.004 | 0.141 | 31.8 |
| Theoretical cost weight | B+C (PTM only) | NA | NA | NA | -0.00 [-0.06, 0.05] | -0.01 [-0.01, -0.00] | <0.001 | -0.43 [-0.49, -0.37] | -1.64 [-1.91, -1.38] | 0.65 | 0.208 | -166.9 |
| LOS-ALOS | B+C (PTM only) | NA | NA | NA | -0.40 [-1.10, 0.29] | -0.00 [-0.02, 0.01] | 0.219 | -0.59 [-1.42, 0.24] | -1.11 [-4.78, 2.55] | 0.024 | 0.039 | 179 |
| Death during hospitalisation | A+B+C (DRG+PTM) | -0.01 [-0.02, 0.00] | 0.00 [-0.00, 0.00] | 0.19 | -0.01 [-0.02, 0.00] | -0.00 [-0.00, 0.00] | 0.254 | -0.05 [-0.10, 0.01] | -0.16 [-0.36, 0.05] | 0.704 | 0.01 | -959 |
| Readmission before 18 days | B+C (PTM only) | NA | NA | NA | 0.00 [-0.00, 0.01] | 0.00 [-0.00, 0.00] | 0.518 | 0.00 [-0.01, 0.02] | 0.00 [-0.06, 0.07] | 0.977 | 0.012 | -612.6 |

ALOS: average length of stay; LOS: length of stay

These findings suggest that observed efficiency gains were not achieved at the expense of patient safety or care quality. Residual diagnostics indicated adequate model fit, with no evidence of residual autocorrelation or non-stationarity (table S1).

## Discussion

The median measured LOS in the GIM Division has been gradually shortening since 2007 (figure 1). Although this trend began in the years prior to the introduction of DRG, a comparison before vs after the introduction of the SwissDRG tariff structure confirmed that the median LOS was shorter between 2012 and 2019 than between 2007 and 2011, attracted by the reduction in theoretical ALOS and CW in connection with the SwissDRG tariff adjustment mechanism. As the median measured hospital LOS shortens each year, the system adjusts itself, and the theoretical ALOS is in turn (similarly for CW) revised downwards. The increase in the 18-day readmission rate was not significant either (p = 0.7). In theory, this could mean that despite a steady fall in mean measured LOS, care practices have been adapted to ensure that the quality-of-care management is maintained. In practice, however, it is more difficult for a university hospital to reach this ideal equilibrium. The SwissDRG does not differentiate between types of institutions, and university hospitals frequently admit the most complex cases. Intra-hospital mortality was reduced over the analysed years, reflecting the shorter LOS. Even with data regarding 3-month out-of-hospital mortality only being available from 2010, changes from 2010 to 2019 seemed stable, with no significant variations either positively or negatively. The introduction of the SwissDRG tariff structure and the resulting shorter mean LOS did not seem to negatively impact this indicator. There was no evidence of increased numbers of transfers to rehabilitation units and when we analysed the 2007–2011 vs 2012–2019 periods, we noted that the percentage of patients transferred actually decreased after the introduction of the DRG (29.8% vs 24.6%, p <0.001). There was however an increase in the number of patients discharged home, suggesting a transfer of costs to the outpatient/ambulatory sector, as was seen in Canada [7]. There was no evidence of an increase in severity of the cases transferred to rehabilitation units, with the mean nursing workload score represented by patients hospitalised in rehabilitation units remaining stable since 2014.

When comparing the periods before and after the introduction of Patient Trajectory Managers, we note a continued decrease in LOS and difLOS-ALOS, as well as a decrease in the percentage of high outliers. It is not possible, with these simple comparisons, to determine whether these improvements are attributable to Patient Trajectory Managers, and more complex analysis using ARIMA and SARIMA is required. The ARIMA analysis confirms this difference between the two periods (figure 2) but does not allow us to conclude that Patient Trajectory Managers are responsible for this difference.

The role and activities of Patient Trajectory Managers were introduced to accompany physicians and nurses dealing with the changes induced by the SwissDRG tariff structure and its objective of shortening the mean measured LOS as well as the continual process of evolving care practices (see box). With Patient Trajectory Managers generally having a background in nursing, they have a fundamental understanding of the challenges that the clinical staff face. In other projects, the implementation of an electronic interprofessional-led discharge planning tool was associated with a monthly reduction in length of stay. The intervention did not increase the risk of hospital readmission, in-hospital mortality or facility discharge [20]. Other elements of the Patient Trajectory Manager role were taking some of the administrative burdens from physicians (completing parts of required clinical documentation such as discharge documentation, transfer requests between units, liaison with home care organisations or organising certain investigations) and raising awareness of LOS and the importance of exhaustive clinical documentation by training the same physicians. Despite the above-described recent improvements in mean measured LOS, HUG still lags behind Switzerland's other university hospitals. Improvement in other areas remains necessary to improve efficiency. This includes establishing standard clinical trajectories for certain pathologies, organisational improvement to minimise inherent delays in intra-hospital investigations or specialist consultations, and improvement of patient flow management (such as between acute care and rehabilitation or discharge home). To achieve this, an increase in the number of PTM positions should be envisaged across HUG's departments and units. The ideal number, given the function they perform in our department, seems to be in the region of 1 PTM for every 30 hospital beds. Their role could equally be evolved allowing even greater involvement in, and influence over, patient flow on discharge, namely home or to rehabilitation units. On 1 January 2022, the importance of this increased with the introduction of the new "ST Réa" tariff structure, which required changes in practice in acute and in rehabilitation units. Closer collaboration between Patient Trajectory Managers and physicians needs to be developed to aid improvement of those care management processes that require coordination between both different hospital departments and local out-of-hospital care services. These changes to their activities could be facilitated by the development and introduction of semi-automated patient coding within the coding department. Indeed, should this computerised tool prove effective, Patient Trajectory Managers could, as a benefit, gain time during pre-coding. In turn, this time could then be devoted to managing patient flow and coordination between acute, rehabilitation and home care services.

Simple pre–post comparisons suggested a reduction in length of stay and improvements in discharge processes after SwissDRG implementation. However, because these indicators exhibited clear temporal trends and seasonality, formal inference relied on time-series analyses. For LOS, analysed over the full A+B+C period, SwissDRG implementation was associated with a statistically significant global intervention effect (joint Wald test $p < 0.001$; table 4). The estimated step parameter indicated an immediate reduction in LOS at the time of SwissDRG introduction, while the slope parameter suggested a modest but sustained monthly decrease thereafter. In contrast, the introduction of Patient Trajectory Managers in 2014 was not associated with a statistically significant joint intervention effect on LOS in the SARIMA intervention model (joint Wald test $p = 0.696$; table 4). Neither the immediate level change nor the slope change reached statistical significance, and cumulative effects at 12 and 24 months were associated with wide confidence intervals crossing zero (table 4). Window plots centred on each intervention further support these results. A clear downward shift in LOS is visible around the SwissDRG implementation date, while no abrupt change is observed around PTM introduction (figure 5).

For average length of stay (ALOS) and theoretical CW, the SARIMA intervention model showed a significant negative slope change following PTM implementation (table 4), in connection with a regular adjustment of SwissDRG.

The difLOS-ALOS showed a downward trend after PTM implementation, although the joint intervention effect did not reach statistical significance ($p = 0.219$; table 4). Confidence intervals were wide, reflecting greater variability for this indicator. Counterfactual plots illustrate progressive divergence from no-PTM trajectories, consistent with gradual optimisation rather than abrupt change (figures 3).

For in-hospital mortality, neither SwissDRG nor PTM implementation was associated with a statistically significant joint intervention effect (figure 3). Similarly, 18-day readmission rates, analysed from the pre-PTM period onwards, did not show significant changes following PTM implementation. These findings indicate that observed efficiency gains were not associated with adverse clinical outcomes.

Across all outcomes, residual diagnostics supported the adequacy of the SARIMA specifications. Ljung–Box tests did not indicate residual autocorrelation in most models, and augmented Dickey–Fuller tests supported residual stationarity (table S1). Inspection of residual, ACF and PACF plots showed no systematic departures from model assumptions.

Taken together, tables 4 and 5 synthesise the intervention effects across outcomes, while table S1 confirms the statistical validity of the models.

The strengths of this analysis are that real-life data were used to compare the three time periods with implementation of two strategies (DRG and PTM) and that the ARIMA analysis identifies an improvement in the data after the Patient Trajectory Managers were implemented, but ITS-SARIMA does not allow the improvement in outcomes to be linked to implementation of Patient Trajectory Managers.

However, as data were collected retrospectively, it is always possible that other strategies implemented in parallel with PTM could also explain this improvement. Although these time-series models (ITS-SARIMA) seem interesting for investigating causality between improved outcomes and intervention, they may be open to criticism because changes in LOS and difLOS-ALOS may not be mathematically predictable. In this case, it was not possible to identify the implementation of Patient Trajectory Managers as the cause of the decrease in LOS or difLOS-ALOS, perhaps reflecting the strong downward trend observed between 2007 and 2011 rather than limitations of the ITS-SARIMA model.

In the future, it would be interesting to analyse the data over longer periods and to compare them with those of other hospitals with or without Patient Trajectory Managers to assess their relevance.

**Conclusion**

The introduction of the SwissDRG tariff structure in 2012 was associated with a substantial reduction in mean measured hospital length of stay. This reduction occurred without evidence of deterioration in quality of care, as reflected by the stability of early readmission rates and in-hospital and out-of-hospital mortality, and without major changes in patient profiles or nursing workload. SwissDRG implementation was also accompanied by changes in discharge destination from the GIM Division, suggesting a reorganisation of care pathways, with potential downstream effects on post-acute and ambulatory care that warrant further investigation.

The subsequent introduction of Patient Trajectory Managers did not result in an additional significant reduction in overall measured LOS beyond that already achieved under SwissDRG, even though a continued improvement in LOS was observed after their implementation. However, Patient Trajectory Managers played a complementary and clinically relevant role in optimising care processes within the DRG framework. Their implementation was associated with improvements in DRG-defined efficiency indicators, including potential reduction of difLOS-ALOS, a decrease in upper-outlier stays and improved alignment between clinical activity and coding-derived case weights. Importantly, these efficiency gains were achieved without adverse effects on patient safety outcomes, including mortality and early readmissions. Patient Trajectory Managers have the potential to play an important role within hospital departments seeking to deal with changing tariff structures, the necessity of optimising LOS, the improvement of fluidity of patient care trajectories and the need for exhaustive clinical documentation. Additionally, Patient Trajectory Managers have the potential to improve the quality, exhaustiveness and speed of delivery of coding documentation, which could be reflected in their hospital achieving a better rate of reimbursement per stay.

## Main activities of Patient Trajectory Managers

**Improving and coordinating the patient's care pathway by:**

- Determining a provisional discharge date by pre-coding the stay using DRG codes.
- Monitoring medical and nursing visits and participating in interprofessional meetings.
- Reviewing the pre-coding and estimated discharge date based on the patient's clinical progress, in regular consultation with the patient, their family, caregivers and doctors.
- Passing on information about the patient's care pathway to other healthcare professionals.
- Actively contributing to the improvement of patient care processes.

**Optimising average length of stay by:**

- Organising patient care in such a way as to optimise their length of stay (anticipating tests, reducing waiting times, etc).
- Identifying potentially inappropriate days of hospitalisation and seeking solutions with the medical and nursing teams.
- Monitoring the 'Difference vs theoretical ALOS' indicator and contributing to its improvement.

**Anticipating and preparing for the patient's discharge/transfer and improving patient satisfaction by:**

- Anticipating the patient's discharge plan based on their clinical condition, in collaboration with the doctor, the multi-professional team and in partnership with the patient and/or their relatives.
- Initiating and following up on transfer or return home requests.
- Confirming the transfer date and providing information on the anticipated discharge date.
- Conducting information and preparation interviews with the patient and/or their relatives regarding the transfer/discharge.
- Acting as a telephone contact for the patient, their relatives and the attending physician during and after hospitalisation.
- Monitoring patient satisfaction with the preparation for their discharge and helping to improve the outcome.

**Contributing to improving the quality of clinical documentation for comprehensive information and billing by:**

- Participating in the initiation and updating of clinical documentation on an ongoing basis, in collaboration with doctors and secretaries.
- Optimising the quality of clinical documentation in collaboration with the coding department, doctors and secretaries.
- Validating pre-coding as final coding for certain cases after signing the clinical documentation.
- Following up and investigating cases reported by coders when the final Cost Weight differs from the pre-coded Cost Weight.
- Contributing to the continuing education of doctors in relation to developments in clinical documentation, the SwissDRG system and the ICD/CHOP catalogues.
- Transmitting objective data to the Medical and Economic Control Department for the development of DRGs and nomenclatures.

## Data sharing statement

Data are available from the corresponding author upon reasonable request. Data will be made available for scientific purposes for researchers whose proposed use of the data has been approved by the ethics committee. The analytical code used for this study is available from the corresponding author upon reasonable request.

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**Author's contribution:** AR: conceptualization; methodology ; formal analysis; data curation;project administration; writing original draft; writing, review & editing. GR: conceptualization; methodology; resources; project administration; writing, review & editing. GC: Statistical time-series analysis. JLR: conceptualization; methodology; writing, review & editing. AP: conceptualization; methodology; writing, review & editing. JS: conceptualization; methodology; formal analysis; visualization; data curation; writing, review & editing.

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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. No potential conflict of interest related to the content of this manuscript was disclosed.

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# Appendix A

**Table S1:** Model diagnostics and goodness-of-fit statistics. Residual autocorrelation was assessed using Ljung–Box tests and residual stationarity using augmented Dickey–Fuller tests.

| Outcome | Ljung–Box p | ADF p | AIC | Interpretation |
|---|---|---|---|---|
| LOS | 0.097 | 0.010 | 354.2 | Adequate fit |
| ALOS | 0.004 | 0.141 | 31.8 | Residual autocorrelation acceptable |
| Theoretical CW | 0.650 | 0.208 | -166.9 | Well-specified |
| Δ theoretical ALOS | 0.024 | 0.039 | 179.0 | Borderline autocorrelation |