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Hospital outcomes and healthcare staffing: a 12-year longitudinal study including the COVID-19 pandemic

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Abstract

Background

Inpatient hospital outcomes are the results of general trends in the characteristics of the concerned population, the evolution of the healthcare offer, the various management efforts to improve efficiency and effectiveness, as well as the hazard of unexpected health crises. Within the DRG-based French financing system, a 12-year longitudinal analysis (2012-2023) was performed at the Georges Pompidou University Hospital (HEGP) in Paris to provide and assess the simultaneous evolution of various inputs, outputs, and outcomes.

Methods

Explanatory variables extracted from the HEGP information system include the time of admission, patients' age, sex, the nature of stay, several morbidity conditions, the Elixhauser severity index (ESI), and two indicators of the physician and nursing staff load. Selected outputs and outcome measures include the number and length of stays (LOS), the inpatient stay mortality, the readmission (RA) rate, and 6 potentially avoidable complications (PACs). Relationships between explanatory conditions and outcomes are analyzed for the pre-COVID (2012-2019), per-COVID (2020-2023), and overall COVID (2012-2023) periods to contrast the long-term changes and the specific COVID-19 associated changes.

Results

The pre-COVID period is characterized by a regular and significant increase in the total number of stays, day stays, the mean patients' age, the ESI, the RA rate, and a decrease in the intensive and surgical care percentages, the male gender ratio, the mean LOS, and the inpatient stay mortality.

During ≥ 48 hours stays and the pre-COVID period, significant PACs increases associated with the nursing and physician staff loads concern pulmonary embolisms, pressure ulcers, sepsis, and prosthesis infections and wound dehiscence in the subgroup of surgical stays.

After adjustment for stay and patients' characteristics, COVID inpatient stays are associated with higher rates of diabetes, pulmonary embolisms, sepsis, respiratory failure, renal failure, sepsis, inpatient stay mortality than non-COVID patients' stays but not with hypertension, obesity, or deep vein thrombosis.

Discussion and conclusion

This 12-year longitudinal analysis of patients at HEGP hospital provides valuable insights into input, output, and outcome indicators. When adjusting for confounding factors, the increasing activity associated with increased nurse and physician workload and various PACs increases needs to be related to the search for increased financial efficiency. The significance of COVID-19 several comorbidities depends on the selected stay and patients' characteristics adjustments. Results highlight the need for continued efforts to provide the best balance between efficiency- and effectiveness-oriented health strategies.

Keywords. Outcome research, Continuous healthcare quality improvement, Inpatient mortality, Patient safety, Avoidable complications, COVID comorbidity factors

Author summary

Why was this study done?

- Inpatient hospital activity and outcomes are the results of multiple factors including the national context and policies, and the hospital and patients' characteristics.
- Financing systems are expected to optimize both outputs and outcomes.
- A major hazard such as the COVID-19 outbreak is likely to induce significant changes in the achieved equilibrium.
- A longitudinal follow-up study is expected to better understand the adaptation of an institution to its efficiency and effectiveness objectives.

What did the researchers do and find?

- A 12-year longitudinal analysis (2012-2023) was performed at the Georges Pompidou University Hospital (HEGP) in Paris to provide and assess the simultaneous evolution of various inputs, outputs, and outcomes including possibly avoidable complications (PACs).
- During the pre-COVID period (2012-2019), factors that could lead to increased financial efficiency include an increased number of stays mainly through day (surgical) care, the reduction of the length of stays, the increasing number of coded diagnoses, the increased Elixhauser severity index (ESI), and the increased number of readmissions.
- In addition to expected risk factors (age, sex, ESI, intensive care, length of stay), pressure ulcers, sepsis, prosthesis infections, and wound dehiscence appear to be positively associated with the increasing nursing and physician staff load.
- Significance of COVID associated comorbidities depend on the selected stays' and patients' characteristics adjustments.
- In a situation of tension on the nursing and medical staff, the four years per-COVID period is associated with a form of health reset annihilating the results of the eight previous years of effort.

What do these findings mean?

- This longitudinal study gives specific information on trends on outputs and outcomes than can be related to changes in the search for increase efficiency in the French DRG based financing system.
- Comorbidity factors commonly attributed to COVID-19 such as hypertension, diabetes, obesity, thromboembolic events should be interpreted within the larger framework of long-term changes in the underlying population and other associated morbidity conditions.
- In a context of increasing activity, the regular and simultaneous increase of several possibly avoidable complications (PACs) could be mediated by the associated increases of the nursing and physician staff load.
- Due to the strong collinearity between admission time and health professional staff during the pre-COVID period, complementary analyses are required to extend the analysis to broader situations but also smaller time granularity to better assess the proper role of tensions on permanent nursing and physician staff load and absenteeism variations on PACs during such healthcare crisis.

Introduction

Hospital outcomes research is of particular relevance in the context of long-term studies and the hazard of pandemic situations such as the 2020 COVID-19 outbreak.¹⁻³ Quantitative studies commonly rely on sets of indicators that are likely to be classified in terms of inputs, outputs, and outcomes and try to determine the efficiency and effectiveness of healthcare interventions.⁴⁻⁸ Inputs include the different resources involved in the hospitals such as the number of beds and their organization, the numbers and quality of health professionals, the pieces of equipment, as well as the engaged expenses. Outputs include the measured activity in terms of patient care, professional education, research production, as well as the institution's financial income related to these activities. Outcome measures to assess the quality of hospital care generally focus on two main aspects.⁹⁻¹⁰ On one hand, the patient's state of health following medical care includes indicators such as mortality rates, complication rates, readmission rates, and improvements in their overall health and well-being. On the other hand, outcome indicators account for the patient's experience with the care provided by the hospital, encompassing factors such as patient satisfaction, communication with healthcare providers, and the responsiveness of hospital staff to their requests.¹¹⁻¹⁵ Input indicators can be considered as determinants of output indicators, and both input and output as determinants of outcome.⁴⁻⁵

Three commonly used outcome measures to assess the quality of care in hospitals are the length of stay (LOS), the hospital mortality, and the readmission rates.¹⁶⁻¹⁹ Assessment of potentially avoidable complications is likely to be coupled with the three previous indicators.²⁰⁻²² However, these results are interrelated, and the interpretation of hospital outcomes can be complex. This is particularly the case of patients who die in the hospital due to uncontrolled comorbidities or complications, and therefore cannot be readmitted. In extreme situations, hospitals could have low readmission rates due to excessively high inpatient mortality.

Contextual information can be considered as external factors susceptible to influence inputs, outputs, and outcomes or the relationships between them.²³⁻²⁵ Examples include the geographic, political, and financial context, the achievability of health goals, the characteristics of the population involved, and their expression through case-mix changes in the short- and long-term ranges.

Multiple research studies that examine the relationship between explanatory indicators and outcomes rely on cross-sectional data.^{1-2 26-27} They are subject to inconsistent findings. In contrast, longitudinal data analyses from data warehouses (i.e., through data reuse from health/hospital information systems) give an opportunity to discriminate between long-term trends and the hazard of acute situations such as the COVID-19 pandemic.

A preliminary longitudinal analysis for all hospitals in France for the period 2013-2017 was done to compare the differentiated trends between not-for-profit and for-profit hospitals.²⁶⁻²⁷ But the analysis was performed on groups of patients without direct access to the individual patients' stays and their chaining, with a one-year granularity of analysis, and a small period of follow-up (5 years). The objective of this longitudinal study on the data warehouse of a public university hospital (the Georges Pompidou University Hospital in Paris) is to simultaneously analyze trends on a limited and selected number of indicators observed during a sufficiently long period (2012-2023) including the COVID-19 pandemic. The study relies on individual stays' data, exact admission times, and the coding of multi-morbidities. The main hypothesis is that changes, when observed, could be linked to an unbalanced strategy for improving efficiency and quality in the context of the French DRG financing system.

Material and Methods

The Georges Pompidou University Hospital (HEGP)

The Georges Pompidou European Hospital (HEGP) is an 800-bed acute care university hospital located in southwest Paris. The hospital is composed of three main cooperating centers, namely cardiovascular, cancer, and internal medicine with its urgency department and a trauma center. HEGP does not have paediatric, obstetric, and rehabilitation departments.

Data collection and study period

Since its opening in July 2000, HEGP has relied on an integrated hospital/clinical information system (HIS/CIS) including its clinical part made of five main components: an identification, admission/discharge/transfer (I-ADT) component, a permanent multimedia electronic health record (EHR) covering both in and outpatient care, a computerized provider order entry (CPOE) system with decision support capabilities, an appointment and scheduling system, and a clinical data warehouse (CDW).²⁸⁻²⁹ The CDW that shares its concept dictionary with the other components is updated every week from a mirrored HIS database and used for most statistical analyses. All computer applications have been declared and validated by the National Commission for Informatics and Liberties (CNIL).

The current study uses patient admission stays recorded at HEGP from January 1st, 2012, to December 31, 2023. A patient's unique internal identifier allows the chaining of the different stays within the hospital and the exact calculation of post-discharge readmission rates within the same hospital. All data are processed anonymously according to the local ethical board requirements.

Patients and hospital stays' characteristics

The dataset includes patient demographics, hospital stays' characteristics (i.e., day care versus regular inpatient stays, surgical stays vs. non-surgical stays, main and associate diagnoses, and therapeutic procedures. Stays have an administrative/financial definition that corresponds to one or several strictly successive movements of a given patient within the hospital (e.g., from the urgency department to a medical or surgical ward). A stay including a surgical procedure is considered a surgical stay. Diagnostic procedures performed within an operating room (e.g., endoscopic analysis) are not considered surgical stays. Short therapeutic care sessions (e.g., dialysis, chemotherapy or radiotherapy) are not considered in this work as inpatient regular care stays but as outpatient visits and are excluded from inpatient day care stays.

The yearly nursing staff load is calculated as the ratio of the number of inpatient stays during a considered period divided by the mean number of full-time-equivalent (FTE) registered nurses (RN) and physicians (RP) during the same period.

For regular inpatient stays, the length of stay (LOS) is calculated as the exact difference between the date/hour of admission and the date/hour of discharge. Within the regular inpatient stays, ≥ 48 hours stays are denominated here as complete admissions (CA). This subset is used for the estimation of possibly avoidable complications (PACs).

Diagnoses are coded according to the International Classification of Diseases, 10th Revision (ICD-10) and grouped into 25 major diagnostic categories (MDC). The list of Diagnosis-Related Groups (DRG) in the French PMSI system includes approximately 2600 DRGs and 670 root groups and is maintained by ATIH, a central government agency.³⁰ Diagnosis and procedure codes are directly entered at the discharge time by health professionals (physicians, nurses, and secretaries) who have access to the records of the patients they are in charge of. During the DRG coding procedure health professionals are provided with all the codes of previous stays of the same patients. They also benefit from the support of professional coders from the hospital health informatics department. Control of the quality of DRG coding is performed internally by medical information technicians who also

perform DRG coding optimization. External evaluations are routinely performed by the Ministry of Health on randomly extracted patient records with financial sanctions for the over-coding hospitals.

Each hospitalization stay summary is transmitted to the French national insurance agency. It includes one primary diagnosis code that corresponds to the reason for hospitalization of the patient, and as many associated diagnoses and/or procedural acts as needed. All these diagnoses are considered as morbidity conditions in this longitudinal study whether coded as primary or associated diagnosis. Detailed ICD10 codes used in this survey are given in Appendix Table A1. Procedure codes use a National-specific terminology (CCAM) and are used for the precise DRG attribution³¹.

The Elixhauser severity index that relates to 30 morbidity conditions is directly calculated for any given stay from the set of coded diagnoses.³² Diagnosis and act coding, which are mandatory for French hospital financing, are close to 100% for the 2012-2023 study period. The mean number of coded diagnoses is considered as a multi-morbidity indicator.

Clinical Outcomes Measures

Outcome measures include the length of stay (LOS), the within-stay mortality, the readmission rates (RA), and six within-stay PACs. In-hospital mortality is calculated as the rate of deaths for a given number of stays. Within 30 days mortality after discharge was not available and not considered in this statistical analysis. Readmission is defined as a new admission at HEGP within 30 days of the patient's day of discharge. Readmissions outside HEGP are not considered in this statistical analysis.

An indirect evaluation of within-stays PACs is calculated for complete admissions (i.e., ≥ 48 h stays). Using the ICD10 definition of Appendix 1, only diagnoses coded as associated diagnoses and not as primary diagnostic are considered here. Six conditions, selected among the AHRQ (Agency for Healthcare Research and Quality) patient safety indicators, known to be possibly associated with the health professional density, were analyzed: pulmonary embolism, deep vein thrombosis, pressure ulcers, sepsis, and osteo-prosthesis infections and post-operative wound dehiscence in the subgroup of surgical stays.^{20 33-38}

Statistical analysis

To simplify the presentation of table results, the 581,152 concerned stays are grouped by periods of two years in Table 1. Time trends in the 2012-2019 and 2012-2023 periods are analyzed separately to evaluate the effect of the COVID-19 pandemic on various indicators. *p* values in Tables 1 and 2 are obtained on the ungrouped data using regression analysis for quantitative variables and logistic regression for binary variables. The exact time of admission is used as the dependent variable. The same approach is used in Tables 3, 5, and 6 but after adjusting either for age and sex or by several stays and patient characteristics to test the residual time trends. During the specific per-COVID period (2020-2023) COVID - and COVID + patients' stays are compared (Tables 3 and 5) allowing the calculation of the odds ratios with their confidence intervals. Considering the high number of values and the multiplicity of tests performed, Bonferroni corrections were systematically used for morbidity *p* values calculations.

Multivariate analyses are performed using logistic regression models. The analyses are conducted with SPSS Statistics 29.0 and Amos (SPSS Inc., Chicago, IL, USA). Multicollinearity was tested using the different Variance Inflation Factors (VIFs) of each variable introduced into the multiple regressions.³⁹ In situations of strong collinearity (e.g., $VIF \geq 5$), partial analyses are performed by avoiding the simultaneous introduction in a given model of two highly-collinear variables.

Results

Input and output indicators

HEGP input and output indicators are summarized in Table 1 for the six two-year grouping periods. Results are presented in the context of the trends observed in the French population ≥ 15 years⁴¹. When considering all categories of stays, the pre-COVID-19 period (2012-2019) is characterized by a regular and very significant increase in the patients' mean age, the percentage of patients ≥ 65 years, and a small decrease in the percentage of patients of male sex (-1.97% at HEGP vs +0.30% in France from 2012 to 2019), and patients treated in intensive care. The 2.85% increase of adult patients over 65yrs between 2012 and 2019 in France is associated with a 4.52 % increase at HEGP.

Increased activity at HEGP is expressed by the increasing number of total admissions, the numbers and percentages of day-care and surgical-care stays, and the number of readmissions. From 2012 to 2019 the number of inpatient stays increases by 15.35 % mainly through to the 3.04 % increase of day stays. During the same period the yearly RP and RN staff load increases by 8.84 % and 12.49 % respectively.

By comparison with the 2018-2019 period, the 2020-2021 COVID period was characterized by a significant drop in the number of yearly overall and regular stays (8.24% and 13.50% respectively) with a partial re-increase in 2022-2023.

For the remaining analyses, two main subgroups are considered, the regular admission subgroup obtained by excluding day admissions, and the complete admissions' group corresponding to ≥ 48 hours inpatient admissions.

Morbidity conditions, severity index, mortality, and readmissions

A specific analysis is provided for the nine morbidity conditions of Table 2. Raw morbidity and readmission rates are calculated for each two years considered as well as the exact time trends after adjusting for age and sex. All main and associated diagnoses are considered in this table. During the pre-COVID period (2012-2019) a significant increase is observed for obesity, renal insufficiency, and sepsis. A significant decrease is observed for diabetes, deep venous thrombosis, and respiratory failure. The increase in the Elixhauser score over the same period is not significant. During the per-COVID period (2020-2023), the positive trend for pulmonary embolisms and sepsis is maintained as well as the negative one for deep venous thrombosis. Overall prevalence of diabetes, hypertension, and obesity is lower than during the per-COVID period than the pre-COVID one. COVID+ patients' stay prevalence is still significant during the 2022-2023 period.

COVID+ and COVID- patient characteristics are compared for the 2020-2023 period (Table 3). Mean age, male patients' percentage, intensive care, and LOS are significantly higher in COVID+ patient stays than non-COVID- patients' stays. Odds ratio for surgical care is significantly lower. Overall odds ratio for within stay mortality is as high as 4.75 (4.28 to 5.27) between the COVID+ and non-COVID patients' stays. Lower readmission in COVID+ patients is associated with an odds ratio of 0.85 (0.78 to 0.93) ($p < 0.001$). After adjustment for age and sex, COVID+ inpatient stays are associated with significantly higher rates of hypertension, diabetes, pulmonary embolisms, respiratory failure, renal insufficiency, and sepsis than non-COVID stays (Table 3). After adjusting for stays' characteristics (surgical care, intensive care, LOS) and patient characteristics (age, male sex) associations with hypertension and obesity are no more significant.

Table 1 – Hospital activity and patients’ characteristics

Year	2012-13	2014-15	2016-17	2018-19	2012-19 trend β (p) †	2020-21	2022-23	2012-23 trend β (p) †
All HEGP stays (day and regular stays, ≥ 15 yrs) – 2012-2019 (n = 389 907) & 2012–2023 (n = 581 152)								
Mean yearly admissions in thous.§ – no. (%)	45.01 (100)	47.83 (100)	50.01 (100)	52.11 (100)	-	45.93 (100)	49.69 (100)	-
Day care stays – %	30.74	31.69	31.14	33.48	.0181 ($\ll.001$)	34.86	39.55	.0363 ($\ll.001$)
Surgical care – %	42.52	44.12	44.18	43.16	.0018 (NS)	41.61	45.16	.0022 ($\ll.01$)
Intensive care – %	12.37	11.32	11.12	10.53	-.0282 ($\ll.001$)	10.71	9.42	-.0554 ($\ll.001$)
Patients’ mean age (SD)	58.52 (19.35)	59.16 (19.16)	59.32 (19.37)	59.65 (19.39)	.1686 ($\ll.001$)	60.14 (19.31)	60.32 (19.34)	.1703 ($\ll.001$)
≥ 65 yrs. – %	39.61	41.67	42.53	43.65	.0254 ($\ll.001$)	44.37	45.35	.0217 ($\ll.001$)
Male sex – %	53.12	52.37	52.08	51.40	-.0108 ($\ll.001$)	52.57	52.55	-.0019 ($\ll.05$)
Total hospital staff in thous. – no. (%)	3.40 (100)	3.45 (100)	3.57 (100)	3.57 (100)	-	3.60 (100)	3.57 (100)	-
Registered physicians (RP) \diamond – %	11.22	11.39	11.39	11.29	.0070 ($\ll.001$)	11.39	11.53	.0187 ($\ll.001$)
Registered nurses (RN) \diamond – %	31.00	30.62	30.28	30.32	-.1165 ($\ll.001$)	28.17	26.64	-.4123 ($\ll.001$)
Metropolitan France population (≥ 15 yrs)								
Population in millions – no. (%) \square	53.39 (100)	54.08 (100)	54.57 (100)	55.13 (100)	-	55.49 (100)	56.20 (100)	-
≥ 65 yrs. – % \square	21.58	22.60	23.59	24.41	-	25.00	25.52	-
Male sex – % \square	47.80	47.79	47.76	47.77	-	47.75	47.82	-
Registered physicians (RP) \diamond – %	7.88	7.93	8.02	8.16	-	8.26	8.29	-
Registered nurses (RN) \diamond – %	29.99	30.19	30.23	30.17	-	29.73	29.04	-

† = β and p -value for time variations using logistic regression for binary values and regression analysis for quantitative variables; § = Raw means and percentages; \diamond Full Time Equivalents, Sources DREES³²; OECD⁴³; SD = Standard deviation.

Table 2. – Morbidity conditions, severity index, and outcome indicators – HEGP regular inpatient stays. 2012-19 (n = 265.886). 2012–23 (n = 385.800) periods

Year	2012–13	2014–15	2016–17	2018–19	2012–19 trend β (p) †	2020–21	2022–23	2012–23 trend β (p) †
Activity figures and patients' characteristics								
Mean yearly admissions in thousands§ – (%)	31.17 (100)	32.67 (100)	34.44 (100)	34.66 (100)		29.92 (100)	30.04 (100)	
Surgical care – %	45.04	45.17	45.18	45.35	-.00004 (NS)	44.32	45.09	-.0018 (NS)
Intensive care – %	17.86	16.57	16.15	15.83	-0,0231 (<<.001)	16.44	15.55	-0,0451(<<.001)
Patients' mean age (SD)	60.1 (20.01)	60.99 (19.73)	61.45 (19.76)	61.71 (19.89)	.2514 (<<.001)	61.89 (19.88)	62.51 (20.03)	.2109 (<<.001)
≥ 65 yrs. – %	44.11	46.66	48.15	49.31	.0327 (<<.001)	49.32	51.24	.0254 (<<.001)
Male sex – %	53.41	53.14	53.17	52.9	-.0025 (NS)	53.91	53.41	.001 (NS)
Mean Elixhauser severity index (SD)	3.21 (5.71)	3.24 (5.73)	3.45 (5.89)	3.30 (5.69)	.0037 (NS)	2.96 (5.37)	3.01 (5.30)	-.04 (<<.001)
Mean no. of coded diagnosis (SD)	4.93 (4.53)	5.33 (4.74)	5.59 (5.17)	5.44 (4.81)	.0668 (<<.001)	5.14 (4.64)	5.72 (4.56)	.0375 (<<.001)
Outcome indicators								
Mean length of stay in days (SD)	4.82 (6.91)	4.74 (6.37)	4.69 (6.33)	4.59 (6.48)	-.0446 (<<.001)	4.60 (6.51)	4.46 (7.03)	-.0385 (<<.001)
Within-stay mortality – ‰	21.73	20.15	18.92	17.95	-.0423 (<<.001)	24.40	20.37	-.0054 (NS)
Readmissions§§ – %	13.83	15.09	14.95	15.51	.016 (<<.001)	15.12	14.31	.0013 (NS)
Morbidity conditions††								
Diabetes – ‰	107.91	110.66	103.75	100.11	-.0232 (<<.001)	89.98	86.20	-.0324 (<<.001)
Hypertension – ‰	205.14	227.36	233.48	220.21	.0041 (NS)	184.65	178.39	-.0305 (<<.001)
Obesity – ‰	70.52	72.18	88.67	95.10	.0586 (<<.001)	80.57	68.64	.0074 (<.001)
Pulmonary embolism – ‰	20.32	21.35	19.99	22.51	.0095 (NS)	25.64	27.25	.0299 (<<.001)
Deep vein thrombosis – ‰	13.86	10.38	10.37	10.81	-.044 (<<.001)	10.73	8.72	-.0342 (<<.001)
Respiratory failure – ‰	74.86	65.91	61.84	59.32	-.0462 (<<.001)	72.85	68.97	-.0081 (<.001)
Renal failure – ‰	113.40	115.80	125.58	118.40	.0082 (<.05)	120.08	112.58	-.0035 (NS)
Sepsis – ‰	34.36	40.84	42.06	39.50	.0165 (<.01)	43.07	44.78	.0168 (<<.001)
Covid-19 – ‰	-	-	-	-	-	60.92	29.55	.4052 (<<.001)

† =Time β and p values trends adjusting for age and sex in regressions analysis for quantitative variables and logistic regression for binary values. Morbidity p values are given after Bonferroni correction; § = Two-year periods raw means and percentages; SD = Standard deviation; †† = Diagnoses coded as main or associated diagnosis; ‰ = row rate per 1000 stays; §§ = Within 30 days after discharge.

Table 3 – Morbidity, severity index indicators according to the COVID status, HEGP regular stays, 2020-23 period (119 914 stays)

	COVID +§	COBID +§	OR	CI	<i>p</i> †	
Activity figures and patients' characteristics						
Number of regular in thousands – no. (%)	114.50 (100)	5.42 (100)	-	-	-	
Surgical care – %	46.24	12.26	.1620	[.150 - .176]	«.001	
Intensive care – %	12.21	30.37	3.1360	[2.952 - 3.332]	«.001	
Patients' mean age (SD)	61.97 (19.98)	67.22 (18.76)	-	-	«.001	
≥ 65 yrs. old patients – %	49.86	59.17	1.4570	[1.378 - 1.54]	«.001	
Male sex – %	53.46	57.91	1.1980	[1.133 - 1.266]	«.001	
Mean Elixhauser severity index (SD)	2.95 (5.31)	3.69 (5.76)	-	-	«.001	
Mean no. of coded diagnosis (SD)	5.33 (4.56)	7.50 (5.13)	-	-	«.001	
Outcome indicators						
Mean length of stay in days (SD)	4.42 (6.64)	6.96 (8.86)	-	-	«.001	
Within-stay mortality – %	19.38	85.84	4.7510	[4.282 - 5.272]	«.001	
Readmissions§§ – %	14.79	12.90	.8536	[.784 - .929]	«.001	
Morbidity conditions ◊						
Diabetes – ‰	86.09	130.33	1.5909	[1.466 - 1.726]	β_1 (<i>p</i>) ††	β_2 (<i>p</i>) †††
Hypertension – ‰	179.73	219.31	1.2821	[1.200 - 1.370]	.371 («.001)	.2786 («.001)
Obesity – ‰	74.15	83.99	1.1449	[1.038 - 1.263]	.146 («.001)	.0835 (NS)
Pulmonary embolism – ‰	24.52	67.2	2.8663	[2.561 - 3.208]	.205 («.001)	.1316 (NS)
Deep vein thrombosis – ‰	9.66	11.08	1.1483	[.884 - 1.491]	1.014 («.001)	.4560 («.001)
Respiratory failure – ‰	59.29	316.6	7.3509	[6.907 - 7.823]	.158 (NS)	-.1871 (NS)
Renal failure – ‰	59.29	316.6	7.3509	[6.907 - 7.823]	1.934 («.001)	1.4817 («.001)
Renal failure – ‰	113.18	182.76	1.7522	[1.632 - 1.882]	.464 («.001)	.1462 («.01)
Sepsis – ‰	40.65	112.24	2.9840	[2.729 - 3.263]	1.040 («.001)	.6093 («.001)

§ = Four-year periods raw means and percentages; OR = Odds ratio; CI = 95% Confidence Interval [Lower–Upper]; SD = Standard deviation; §§ = within 30 days after discharge; ◊ = Diagnosis coded as main or associated diagnosis (row rate per 1000 stays); † = Raw means and percentages comparison without adjustment; †† = β_1 and *p* values adjusting for age and sex; ††† = β_2 and *p* values adjusting for stays characteristics (surgical care, intensive care, and length of stay), and patients' characteristics (age and sex) in multivariate regression analysis; *p* values are given after Bonferroni correction.

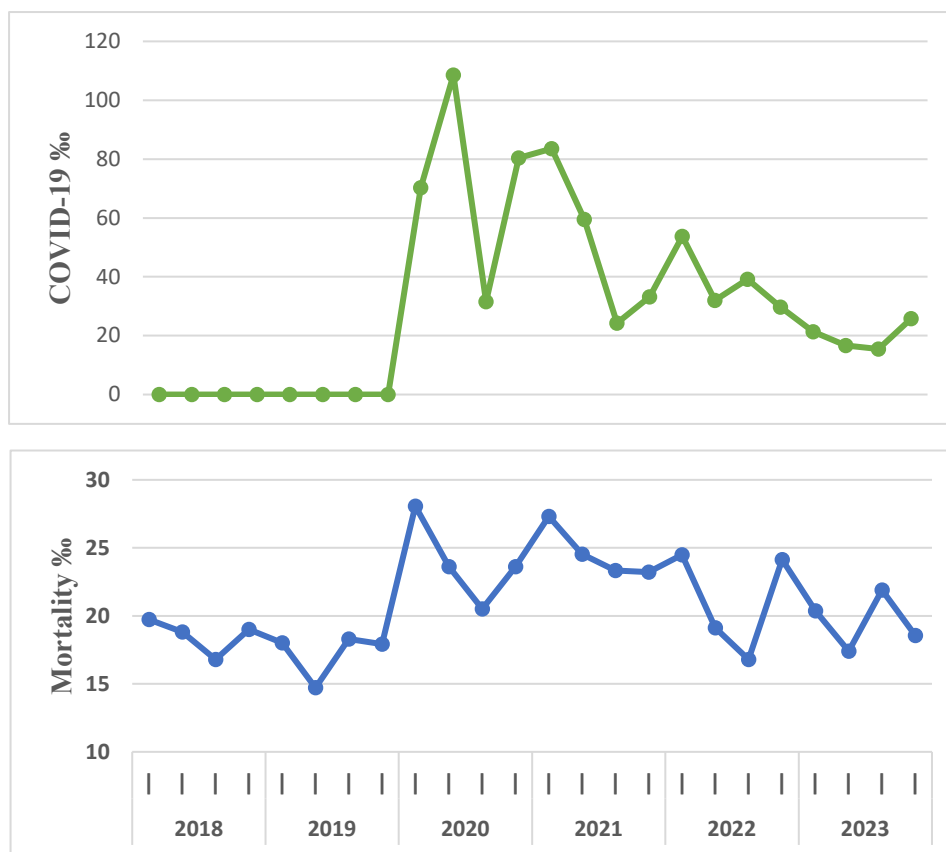


Figure 1. COVID-19 and mortality trends

Outcome indicators

Within-stay mortality decreases significantly during the pre-COVID period to rebound in the 2020-2021 COVID period at a level superior to the 2012-2013 period (Table 2). Mortality during the 2022-2023 period remains high, close to the 2014-15 one. Detailed variations on a three-month basis for the period 2019-2023 are provided in Figure 1 which shows the covariations between the four pics of COVID and inpatient stays' mortality.

As indicated in the methodology part, PACs were only estimated in the complete admission subgroup (i.e., ≥ 48 hours inpatient admissions) and for the pre-COVID period. Associated conditions considered secondary diagnoses and not primary diagnostics are considered plausible PACs in Table 4. Osteoarticular prosthesis infections and wound dehiscence are only estimated for surgical stays. During the 2012-2019 period, and after adjustment for age and sex, significant PAC increases are observed for pulmonary embolisms, sepsis, pressure ulcers, and in the subgroup of surgical care stays osteoarticular prosthesis infections, and postoperative wound dehiscence. Deep venous thrombosis significantly drops, with variations that appear anterior to the COVID-19 pandemic. After stays' and patients' characteristics adjustment, rates of only one of the six PACs analyzed are found significantly higher in COVID+ than in COVID- patients' stays, i.e., sepsis (Table 5).

Collinearity between admission time and staff load is significant (VIF of 7.41 and 17.92 respectively for RN and RP staff) during the 2012-2019 period, and between RN and RP staff (VIF of 11.42). To test the relationship between PACs and the staff load, separate multivariate analyses are performed using each given PAC as the dependent variable and age, sex, LOS, ESI, and either RP or RN staff load as

independent variables (Table 6). Without adjustment for the admission time, the RN and RP staff loads are negatively and significantly associated with LOS and within-stay mortality, and positively and significantly associated with the readmission rate. They are positively and significantly associated with sepsis, pressure ulcers, osteoarticular prosthesis infections, and post-operative wound dehiscence, and negatively with deep venous thrombosis without possible distinction between the respective RN and RP staff loads. When reintroducing the collinear admission time variable, positive and significant PACS associations appear to be non-significant. The readmission rate remains positive and significant with the RN staff load but not the RP staff load.

Table 4 – Potentially avoidable complications and outcomes in complete admissions stays§ (≥ 48h). 2012-19 (n= 155 823) period

Year	2012–13	2014–15	2016–17	2018–19	2012–19 trends β (p) †
Activity figures and patients' characteristics					
Mean yearly admissions in thousands § (%)	18.45 (100)	19.55 (100)	20.07 (100)	19.85 (100)	
Surgical care – %	49.00	49.45	50.24	50.45	.0095 (≪.001)
Intensive care – %	16.67	15.16	15.38	15.23	-.0155 (≪.001)
Physicians staff load◇	118.12	121.59	123.01	129.08	1.6132 (≪.001)
Nursing staff load◇	42.75	45.25	46.29	48.08	.8064 (≪.001)
Patients' mean age (SD)	61.51 (19.22)	59.16 (19.16)	59.32 (19.37)	59.65 (19.39)	.2046 (≪.001)
≥ 65 yrs. – %	46.77	49.04	50.49	51.14	.0285 (≪.001)
Male sex – %	53.32	53.65	53.68	53.34	.0001 (NS)
Mean Elixhauser severity index (SD)	3.96 (6.26)	4.00 (6.26)	4.37 (6.46)	4.23 (6.30)	.0527 (≪.001)
Mean no. of coded diagnosis (SD)	5.81 (4.69)	6.26 (4.84)	6.78 (5.37)	6.69 (4.94)	.1441 (≪.001)
Outcome indicators					
Mean length of stay in days (SD)	7.34 (8.06)	7.16 (7.29)	7.19 (7.32)	7.12 (7.62)	-.0372 (≪.001)
Within-stay mortality – ‰	21.71	20.67	20.41	19.68	-.0231 (<.01)
Readmissions§§ – %	15.05	16.50	16.42	17.28	.0211 (≪.001)
Possibly avoidable complications ∂					
Pulmonary embolism – ‰	13.80	14.45	14.25	16.58	.0231 (≪.001)
Deep vein thrombosis – ‰	14.61	10.31	10.84	12.27	-.0321 (<.01)
Sepsis – ‰	38.08	45.02	50.45	46.45	.0335 (≪.001)
Pressure ulcer – ‰	13.88	17.73	16.49	18.31	.0297 (<.01)
Osteoarticular prosthesis infections□ – ‰	2.10	3.88	6.25	8.14	.2205 (≪.001)
Wound dehiscence□ – ‰	2.82	6.98	8.68	13.33	.2169 (≪.001)

† = β and p values for time variations in multiple regressions adjusted by age and sex; p = p values are given after Bonferroni correction; § = Two-year periods raw means and percentages; ◇ = Calculated as yearly no. stays/no. RP or RN; SD = Standard deviation; §§ = within 30 days after discharge; p values are given after Bonferroni correction; ∂ = Diagnosis coded as associated diagnosis and not as primary diagnosis; □ = surgical stays only (n = 77 604).

Table 5 – Outcome indicators and potentially avoidable complications according to the COVID status, 2020-23 period (66 359 complete stays)

	COVID -§	COVID +§	OR	CI	<i>p</i> †	
Activity figures and patients' characteristics						
Number of admissions in thous. (%)	62.43 (100)	3.93 (100)	-	-	-	
Surgical care – %	49.08	24.32	.3333	[.300 - .370]	«.001	
Intensive care – %	13.08	40.21	4.4691	[4.074 - 4.903]	«.001	
Patients' mean age (SD)	63.21 (18.88)	66.52 (18.90)	-	-	«.001	
≥ 65 yrs. old patients – %	52.25	60.34	1.3908	[1.269 - 1.524]	«.001	
Male sex – %	54.73	59.23	1.2017	[1.097 - 1.316]	«.001	
Mean Elixhauser severity index (SD)	3.88 (5.92)	5.02 (6.58)	-	-	«.001	
Mean no. of coded diagnosis (SD)	6.53 (4.67)	9.92 (5.47)	-	-	«.001	
Outcome indicators						
Mean length of stay in days (SD)	7.17 (7.98)	10.33 (11.19)	-	-	«.001	
Within-stay mortality – ‰	24.01	108.98	4.9708	[4.278 - 5.775]	«.001	
Readmissions§§ – %	16.40	15.57	.9043	[.825 - 1.071]	NS	
Possibly avoidable complications ◊						
Pulmonary embolism – ‰	21.42	53.99	1.5176	[1.077 - 2.139]	β_1 (<i>p</i>) ††	β_2 (<i>p</i>) †††
Deep vein thrombosis – ‰	11.68	14.63	.7463	[.350 - 1.590]	.2481 (NS)	-.2927 (NS)
Sepsis – ‰	49.04	168.52	1.4646	[1.135 - 1.889]	1.3438 («.001)	.3816 (<.05)
Pressure ulcer – ‰	14.03	31.28	1.5127	[.920 - 2.486]	.7549 («.001)	.4139 (NS)
Osteoarticular prosthesis infections◻ – ‰	9.08	8.30	.7781	[.107 - 5.637]	-.0412 (NS)	-.2509 (NS)
Wound dehiscence◻ – ‰	9.68	18.67	1.5274	[.372 - 6.266]	.734 (NS)	.4235 (NS)

§ = Four-year periods raw means and percentages; OR = Odds ratio; CI = 95% Confidence Interval [Lower–Upper]; SD = Standard deviation; §§ = within 30 days after discharge; ◊ = Diagnoses coded as associated diagnoses and not as primary diagnoses (row rate per 1000 stays); † = Raw means and percentages comparison without adjustment; †† = β_1 and *p* values adjusting for age and sex; ††† = β_2 and *p* values adjusting for stays' characteristics (surgical care, intensive care, and length of stay), and patients' characteristics (age and sex) in multivariate regression analysis; *p* values are given after Bonferroni correction.

Table 6 – Influence of the health staff load on possibly avoidable complication – 2012-2019 period (n= 155 823 complete admission stays)

	Nursing staff load				Physician staff load			
	R ²	β (p) †	OR	[CI]	R ²	β (p) †	OR	[CI]
Outcome indicators								
Mean length of stay in days (SD)	.0295	-.0604 (≪.001)	-	-	.0295	-.0240 (≪.001)	-	-
Within-stay mortality – ‰	.1548	-.0279 (<.05)	.9724	[.956 - .989]	.1548	-.0131 (<.05)	.9868	[.979 - .9995]
Readmission – ‰	.0556	.0264 (≪.001)	1.0267	[1.020 - 1.034]	.0555	.0110 (≪.001)	1.0110	[1.008 - 1.014]
Possibly avoidable complications								
Pulmonary embolism††	.1075	.0204 (NS)	1.0206	[1.000 - 1.042]	.1075	.0101 (NS)	1.0101	[1.001 - 1.02]
Deep venous thrombosis††	.0345	-.0489 (≪.001)	.9523	[.932 - .973]	.0341	-.0181 (<.01)	.9821	[.972 - .992]
Sepsis††	.1428	.0417 (≪.001)	1.0425	[1.030 - 1.055]	.1427	.0176 (≪.001)	1.0178	[1.012 - 1.023]
Pressure ulcer††	.0969	.0442 (≪.001)	1.0452	[1.025 - 1.066]	.0774	.0181 (<.001)	1.0182	[1.009 - 1.027]
Osteo-prosthesis infection††□	.1117	.3008 (≪.001)	1.3509	[1.273 - 1.434]	.1082	.1166 (≪.001)	1.1236	[1.098 - 1.15]
Wound dehiscence††□	.0447	.2394 (≪.001)	1.2705	[1.215 - 1.328]	.0433	.0981 (≪.001)	1.1030	[1.083 - 1.123]

† = β and p-value for staff load by multiple logistic regression using the complication as dependent variable and staff load, surgical care, intensive care, age, male sex, ESI, and LOS as independent variables; p values are given after Bonferroni correction; †† == Diagnosis coded as associated diagnosis and not as primary diagnosis; □ = Surgical stays only (n = 77 604); OR = Odds ratio; CI = 95% Confidence Interval [Lower–Upper]; R² = Model goodness of fit

Discussion

Hospital activity trends in the context of the national health system

Inpatient hospital activity and outcomes are the results of the evolution of the surrounding healthcare system, the general trends in the characteristics of the concerned population, the various management efforts to improve efficiency and effectiveness, and the hazard of unexpected crises such as the COVID-19 pandemic. In an activity-based healthcare management system, and more specifically in the French DRG-based financing system, hospitals are expected to increase their activity through higher bed occupancy and shorter lengths of stays, and at the same time to put constraints on the healthcare staff density and hospital spending to avoid unmanageable increase of expenses.^{4-5 42} This second objective is the most difficult to achieve in the context of two simultaneous trends: first, the regular aging of the population with chronic diseases and poly pathologies, and second, the explosion of new investigations and therapeutic procedures that require more specialized care and dedicated health professionals. The results observed at HEGP emphasize these two trends and the tension imposed on the professional staff. The 0.5% increase in the French population at large shows the magnifying effect of population aging on patients' characteristics that contrasts with the small variation in the sex ratio. For a 1% increase in the percentage of patients in France between 2012 and 2019, the increase at HEGP is approximately 2.8 times higher. Increased physicians' and nurses' ETP numbers at HEGP are smaller than the simultaneous increase of the population size and the numbers of registered physicians and nurses in France.⁴⁰⁻⁴¹ Health professional ETPs did increase but in a proportion lower than the general population's increase and the number of inpatient stays. Professional burnout rates reported in the literature were accentuated during the COVID crisis by the lack of health professionals' availability due to transportation issues and mandatory confinement.⁴³⁻⁴⁵

Changes in the patients' characteristics

Case mix changes can be analyzed through the distribution of the coded diagnosis and their grouping into MCDs. Considering the stability of the HEGP departments during the study period, changes observed are considered to mainly reflect the change in the deserved population including the COVID-19 pandemic and the hospital strategy to foster day(-surgery) care. The global shift of the age distribution toward older patients was more pronounced in the regular than the overall stays, and in the complete stays than in the regular stays.

In that respect, the regular increase of both the Elixhauser severity index and the mean number of coded diagnoses for regular inpatient stays and particularly for ≥ 48 hrs. stays reflect the progressive orientation of the less severe patients in the direction of day-care at HEGP as well as in France and many other countries.^{25 46} If the Elixhauser index is commonly considered as a pertinent severity index, the number of coded diagnostics is used in this work as a multimorbidity index that can be also influenced by a global coding optimization strategy to increase DRG reimbursement. This includes a possible upcoding of certain diagnoses or selected procedures unbundling⁴⁷⁻⁴⁸. The temporary drop during the two first years of the COVID-19 pandemic could be explained in this hypothesis by the close focus of health professionals on severe COVID-19 patient management and less on administrative coding tasks.

Hypertension, diabetes, obesity, and some thromboembolic events constitute conditions considered as demonstrated COVID-19 comorbidities in particular within case-control studies published in the early pandemic phase, and have led to search for various pathogenic explanations.⁴⁹⁻⁵⁰ This study suggests that comorbidity analyses should be integrated into the broader analysis of the general population concerned in the long term but also to the adequacy of the statistical adjustments for stays and patients' characteristics. For example, whatever the adjustments used, the significant decrease in deep venous thrombosis during 2012-2019 could be interpreted as the beneficial effect of systematic prevention measures such as low molecular weight heparin administration for patients at risk that was

maintained during the COVID period during which anticoagulant was rapidly proposed as a useful management strategy.⁵¹ This is not the case for pulmonary embolisms which appear in this study to be anterior to the COVID period and maintained at a high level during the per-COVID phase. Disappearance of the significant relationship between COVID-19 and pressure ulcers could indicate that the main mediator of this complication could be the length and nature of stays (intensive care, non-surgical stay) that apply to all stays rather than to the COVID-19 stays.

Outcome trends and health professional staffing

Four major categories of outcome indicators, i.e., the LOS, the readmission rate, the within-stay mortality, and several PACS, are considered in this article. In addition to patients' convenience, shorter lengths of stays are expected to increase the overall activity and the DRG-related income, with the possible side effect of increasing the readmission rate. Both significant trends are observed in this study.

A major observation concerns the significant increase during the pre-COVID period of several PACs, namely pulmonary embolisms, sepsis, pressure ulcers, and during surgical stays osteoarticular prosthesis infection and wound dehiscence and their possible relationships with the increased health staff loading. Interpretation is made difficult in multivariate analyses due to the strong collinearity between the admission time and the RN and RP staff loads on one hand, and the RN and RP staff load on the other one.

Limitations of the study

Our study has several limitations. First, data is provided from a single institution (HEGP). Access to data from multiple hospitals data, such as achieved in our preliminary studies for the 2013-2017 period, help to evaluate between institutions' heterogeneity and assess the generalizability of the results. They should be extended in a longer time frame. Possibly avoidable complications rely on the distinction between primary and associated diagnosis. It is not possible to guarantee that those associate diagnoses were not present at the admission time. The article does not discuss potential confounding variables, such as specific changes in HEGP internal policy and staffing goals, making it difficult to evaluate their impact. However, the use of a large database over 12 years, combining hospital and sociodemographic data, and chained stays' data, facilitates the comprehensive analysis of various hospital and patients' characteristics on output and outcome indicators.

One of the major difficulties concerns the choice of the best indicator to measure the health professional staff load. In our preliminary studies²⁶⁻²⁷, the selected indicator was the number of stays per allowed administrative bed. In a situation of tension among health professionals, some units are temporarily closed with consequent variations in the occupation rate. The preferred indicators in this study are the ratio of stays per number of senior physicians and registered nurses, closer to the physician staff load used by Julbegovic et al.⁵² These two indicators are calculated yearly. The rationale is to smoothen the periodic changes of available staff during the year including seasonal changes. A smaller granularity would be helpful in pandemic situations to integrate absenteeism variations secondary to infectious or social issues.

Conclusions and perspectives

This study underscores the critical importance of ongoing monitoring of long-term healthcare outcomes to ensure comprehensive and accurate data collection for assessment and quality improvement purposes. Utilizing risk-adjusted measures, such as the ESI index, can help address variations in involved populations, thereby improving the precision of outcome data. The findings of this study have the potential to inform decision-makers of the development of targeted interventions aimed at reducing mortality and readmission rates and ultimately enhancing patient outcomes.

Evaluation of the trends in the overall French population was only performed for the period 2013-2017^{33 34} and should be completed by extended multinational long-term longitudinal studies. Statistical associations are not synonymous with causal relationships justifying additional studies and the search for third factors, not studies here, that would be associated both with the time of admission and the staffing load. Simultaneous textual analysis of the inpatient stay reports, and the associated biology/imaging results already stored in the same clinical data warehouse is also a major perspective to better analyze the relationships between the various input, output and outcome indicators and foster the need for continued efforts to provide the best balance between efficiency- and effectiveness-oriented health strategies.

Declaration of competing interest and ethical considerations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The work represents the point of view of their authors and not of the institutions they are associated with. All patients registered for care at HEGP receive a formulary indicating the existence of an EHR. All data used for this article have been processed anonymously according to the local ethical board requirements.

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Authors' contributions

JNY participated in all the steps of this study within the framework of his PhD thesis. As members of the HEGP DRG department, IC, and JG were involved in all the data extraction and quality control procedures. As JNY PhD mentor, PD was involved in the choice of the research topic, the data analysis and interpretation as well as the redaction of the article.

Appendix

Table A1 Sources of ICD-10[†] code selection

Clinical condition §	ICD-10 code
Diabetes ◊	E10, E11, E111, E112, E113, E114, E115, E116, E117, E118, E118, E119, E12, E128, E13, E138, E14, E148
Hypertension ◊	I10, I130, I131, I132, I15
Obesity ◊	E66
Pulmonary embolism ◊	I26
Deep vein thrombosis ◊	I80, I828, I829
Respiratory failure ◊	J80, J951, J952, J953, J954, J96
Renal failure ◊	N17, N18, N19
Sepsis ◊	A4, A41, R572, R65, R651, T814
Covid 19 ◊	U071, U0711, U0712, U0714, U0715, U089, U119
Pressure ulcers (light or severe) ◊	L891, L892, L893, L899
Osteoarticular prosthesis infection◊	T845, T847
Wound dehiscence◊	T813

[†]= International Classification of Diseases (ICD-10). §= ATIH³²; ◊ = coded as primary or associated diagnoses for comorbidities or associated but not primary diagnoses for possibly avoidable complications

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