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Trends in delivery hospitalizations and the impact of ICD-9-CM to ICD-10-CM-PCS transition in Portugal between 2010 and 2018

Catarina de Paraíso Camarinha [a,b,*], Maria Miguel Gomes Oliveira [a,b], Cecília Elias [a,c,d], Miguel de Araújo Nobre [a,e], Leonor Bacelar Costa Nicolau [a,b,d,f], Cristina Furtado [a,d,f,g,h], Andreia Silva da Costa [a,d,i,j], Paulo Jorge da Silva Nogueira [a,b,d,f]

[a] EPI Task-Force FMUL, Faculdade de Medicina, Universidade de Lisboa, Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal
[b] Área Disciplinar Autónoma de Bioestatística (Laboratório de Biomatemática), Faculdade de Medicina, Universidade de Lisboa, Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal
[c] Direção Geral de Saúde, Divisão de Saúde Sexual, Reprodutiva, Infantil e Juvenil, Alameda D. Afonso Henriques, 45, 1049-005, Lisboa, Portugal
[d] Instituto de Saúde Ambiental, Faculdade de Medicina, Universidade de Lisboa, Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal
[e] Clínica Universitária de Estomatologia, Faculdade de Medicina, Universidade de Lisboa, Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal
[f] Instituto de Medicina Preventiva e Saúde Pública, Faculdade de Medicina, Universidade de Lisboa, Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal
[g] Unidade de Epidemiologia, Instituto de Medicina Preventiva e Saúde Pública, Faculdade de Medicina, Universidade de Lisboa. Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal
[h] Instituto Nacional de Saúde Doutor Ricardo Jorge, Avenidade Padre Cruz, 1600-560, Lisboa, Portugal
[i] CIDNUR - Centro de Investigação, Inovação e Desenvolvimento em Enfermagem de Lisboa, Escola Superior de Enfermagem de Lisboa, Avenida Professor Egas Moniz, 1600-190, Lisboa, Portugal
[j] CRC-W-Católica Research Centre for Psychological, Family and Social Wellbeing, Universidade Católica Portuguesa, Palma de Cima, 1649-023, Lisboa, Portugal

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ABSTRACT

Background: Hospital discharge data are essential for maternal health surveillance, clinical research, and healthcare resource allocation. In 2017, Portuguese hospitals transitioned from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) to the International Classification of Diseases, 10th edition, Clinical Modification and Procedure Coding System (ICD-10-CM/PCS), impacting the recording of delivery hospitalizations. This study examines trends in delivery hospitalizations from 2010 to 2018 and assesses the impact of the ICD-10-CM/PCS transition.

Methods: We conducted a register-based observational cross-sectional analysis using data from the National Hospital Discharge Database, covering delivery hospitalizations in public hospitals from January 1, 2010, to December 31, 2018. Delivery episodes were identified using diagnosis codes, normal delivery codes, diagnosis-related group (DRG) codes, and procedure codes. Statistical analyses included descriptive statistics, interrupted time series with segmented regression, and Prophet forecasting models to evaluate trends and the impact of the coding transition.

Results: A total of 673,978 delivery hospitalizations were recorded. The transition from ICD-9-CM to ICD-10-CM/PCS in 2017 had minimal overall impact on delivery trends. DRG codes consistently identified the majority of delivery episodes, with outcome of delivery codes and selected procedure codes showing varying trends. An increase in episodes identified by normal delivery codes and a significant decrease in episodes identified by procedure codes was observed immediately after the ICD-10 transition ($p < 0.001$). The Prophet model indicated improved forecast accuracy for procedure codes when including the ICD-10 transition variable.

Conclusion: The transition to ICD-10-CM/PCS had a limited impact on overall delivery hospitalization trends but significantly affected procedure coding. These findings underscore the importance of considering coding system changes in healthcare data analyses. Further research should incorporate private hospital data and continuously monitor coding practices to ensure reliable health data for research and policy-making.

* Corresponding author. EPI Task-Force FMUL, Faculdade de Medicina, Universidade de Lisboa, Avenida Professor Egas Moniz, 1649-028, Lisboa, Portugal.
E-mail addresses: catarina.paraiso@gmail.com (C. de Paraíso Camarinha), mariamoliveira@medicina.ulisboa.pt (M.M. Gomes Oliveira), cecilia.elias@gmail.com (C. Elias), mignobre@gmail.com (M. de Araújo Nobre), lnicolau@medicina.ulisboa.pt (L.B. Costa Nicolau), cristina.furtado@insa.min-saude.pt (C. Furtado), andreiasilvadacosta@gmail.com (A. Silva da Costa), pnogueira@medicina.ulisboa.pt (P. Jorge da Silva Nogueira).

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Abbreviations

Abbreviation	Full Terminology
DRG	diagnosis-related group
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
ICD-10-CM/PCS	International Classification of Diseases, 10th edition, Clinical Modification and procedure coding system
RMSE	Root Mean Square Deviation

1. Introduction

Hospital discharge summaries and routinely collected data are valuable for public disease surveillance, clinical research, quality assessment, and distribution of health resources [1]. Delivery is a common cause of hospital admission among women of childbearing age, thus making hospital discharge data crucial for maternal health surveillance. The recording of codes representing diagnoses and procedures during a hospital stay has been widely used to identify deliveries, pregnancy complications, and maternal morbidity[2–5]. In Portugal, hospital discharge episodes are recorded and collected in the National Hospital Discharge Database, which includes information from Portuguese public hospitals, covering around 70 % of all inpatient stays and about 85.6 % of the deliveries in 2018 [6,7].

In 2017, all hospitals covered by the Portuguese National Health System changed the coding system used to classify diagnoses and procedures from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) to the International Classification of Diseases, 10th edition, Clinical Modification (ICD-10-CM) and procedure coding system (ICD-10-PCS). While this transition does not affect how physicians provide clinical care to patients, it has imposed new training requirements for physicians responsible for coding activities [8]. During the transition to ICD-10-CM/PCS, a number of health conditions were evaluated nationally, but no studies have assessed the identification of delivery episodes and the consistency of their transition to the ICD-10-CM/PCS coding system. The extent of the impact of this transition on the incidence of delivery episodes and the way hospital discharge data are coded remains unknown.

This study aims to identify trends in delivery discharge episodes from public hospitals between 2010 and 2018 in Portugal and to assess the impact of transitioning from ICD-9-CM to ICD-10-CM/PCS coding on these episodes.

2. Methods

2.1. Study design and data source

We performed a register-based observational, cross-sectional analysis of all hospital admission episodes related to a delivery diagnosis in the Portuguese population. Data from the administrative National Hospital Discharge Database were used for this study, which spanned hospital discharge episodes occurring from January 1, 2010, to December 31, 2018. The database was provided by the Central Administration for the Health System of the Portuguese Ministry of Health (Administração Central do Sistema de Saúde — ACSS).

2.2. Delivery identification

Obstetric delivery episodes were identified using the elements from the method developed by Kuklina et al. [9]: outcomes of delivery, which include outcomes of delivery (diagnosis codes), normal delivery (diagnosis codes), diagnosis-related group (DRG) codes, and delivery-related procedures identified by procedure codes (Table 1). Inpatient clinical diagnoses and procedures were coded by trained medical staff according to the ICD-9-CM before 2017 and the ICD-10-CM/PCS after 2017 [10].

The DRG classification system classifies patients into clinically similar characteristic groups and resource consumption [11]. Using discharge summaries as a source of information, including primary diagnosis, secondary diagnoses, procedures, age, sex, destination after discharge, and days in hospital, to classify each episode and allocate its consumption to hospital resources [12,13].

2.3. Statistical analysis

Descriptive statistics were used to assess the distribution of hospital delivery episodes across the study period. To evaluate the impact of changes in the coding system, from ICD-9-CM to ICD-10-CM/PCS, we used an interrupted time series with a segmented regression model [14] following the Prais-Winsten method [15,16] with a robust variance estimator [17] and the Prophet Forecast model [18].

The Prais-Winsten method uses a segmented regression model following the equation for this study:

$$\textit{Number of Delivery Episodes}_t = \beta_0 + \beta_1 * \textit{time} + \beta_2 * \textit{ICD}_t + \beta_3 * \textit{time after ICD10}_t + \varepsilon_t$$

In this model, the dependent variable is the number of delivery indicator episodes per quarter(t). "Time" is a variable indicating the study time period in quarters, ranging from Q1 2010 to Q4 2018. "ICD" is a variable that captures which coding system was used in quarter t (0 for ICD-9-CM and 1 for ICD-10-CM). "Time after ICD10" is a variable indicating the quarters following the transition to ICD-10-CM/PCS, coded 0 before the transition (Q1 2010 to Q4 2016) and 1 after the transition (Q1 2017 to Q4 2018). The HC0 robust variance estimator was used to adjust the standard errors, accounting for the possibility of non-constant error variance in the model [17]. Documentation of the analytical procedure for the segmented regression, provided as an R code, is available in supplementary material.

To further analyze trends and forecast future values, we applied the Prophet forecasting model by Facebook [18]. This model was run with a quarterly frequency both with and without the inclusion of the ICD-10 variable to observe its impact on forecast accuracy. Prophet's inclusion allowed for the examination of trends, seasonality, and changepoints within the data, providing a robust analysis of delivery episodes trends.

All segmented regression model analyses and Prophet forecast modelling were performed with R 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria). Other analyses were performed with Excel (Microsoft, USA).

3. Results

3.1. Delivery hospitalization episodes

From 2010 to 2018, 673,978 delivery hospitalizations' discharge episodes were recorded in Portuguese public hospitals, ranging from 67,653 episodes in 2014 to 86,545 in 2010 (Table 2). The ICD-9-CM coding system identified 528,543 episodes from 2010 to 2017, while ICD-10-CM/PCS identified 145,435 episodes from 2017 to 2018.

Across the study period, DRG delivery codes covered between 99.2 %

Table 1
Delivery identification elements and identification codes.

Description of the elements	ICD-9-CM Code(s)	ICD-10-CM/PCS Code(s)
Outcome of delivery	V27.0 Outcome of delivery, single liveborn	Z37.0 Single live birth
	V27.1 Outcome of delivery, single stillborn	Z37.1 Single stillbirth
	V27.2 Outcome of delivery, twins, both liveborn	Z37.2 Twins, both liveborn
	V27.3 Outcome of delivery, twins, one liveborn and one stillborn	Z37.3 Twins, one liveborn and one stillborn
	V27.4 Outcome of delivery, twins, both stillborn	Z37.4 Twins, both stillborn
	V27.5 Outcome of delivery, other multiple birth, all liveborn	Z37.50 Multiple births, unspecified, all liveborn
	V27.6 Outcome of delivery, other multiple birth, some liveborn	Z37.51 Triplets, all liveborn
	V27.7 Outcome of delivery, other multiple birth, all stillborn	Z37.52 Quadruplets, all liveborn
	V27.9 Outcome of delivery, unspecified outcome of delivery	Z37.53 Quintuplets, all liveborn
		Z37.54 Sextuplets, all liveborn
		Z37.59 Other multiple births, all liveborn
		Z37.60 Multiple births, unspecified, some liveborn
		Z37.61 Triplets, some liveborn
		Z37.62 Quadruplets, some liveborn
		Z37.63 Quintuplets, some liveborn
		Z37.64 Sextuplets, some liveborn
		Z37.69 Other multiple births, some liveborn
		Z37.7 Other multiple births, all stillborn
		Z37.9 Outcome of delivery, unspecified
Normal delivery	650 Normal delivery	O80 Encounter for full-term uncomplicated delivery
		O82 Encounter for cesarean delivery without indication
Diagnosis-related group (DRG) delivery codes	370 Complicated cesarean section	765 Complicated cesarean section
	371 Uncomplicated cesarean section	766 Uncomplicated cesarean section
	372 Complicated vaginal delivery	767 Uncomplicated vaginal delivery with sterilization and/or dilation and curettage
	373 Uncomplicated vaginal delivery	
	374 Uncomplicated vaginal delivery with sterilization and/or dilatation & curettage	768 Vaginal delivery with operation room procedure except sterilization and/or dilation and curettage
	375 Vaginal delivery with operation room procedure except sterilization and/or dilatation & curettage	774 Complicated vaginal delivery
		775 Uncomplicated vaginal delivery
Selected delivery related procedures	72.0 Low forceps operation	10D00Z0 Extraction of Products of Conception, High, Open Approach
	72.1 Low forceps operation with episiotomy	10D00Z1 Extraction of Products of Conception, Low, Open Approach
	72.21 Mid forceps operation with episiotomy	10D00Z2 Extraction of Products of Conception, Extraperitoneal, Open Approach
	72.29 Other mid forceps operation	
	72.31 High forceps operation with episiotomy	10D07Z3 Extraction of Products of Conception, Low Forceps, Via Natural or Artificial Opening
	72.39 Other high forceps operation	
	72.4 Forceps rotation of fetal head	10D07Z4 Extraction of Products of Conception, Mid Forceps, Via Natural or Artificial Opening
	72.51 Partial breech extraction with forceps to aftercoming head	
	72.52 Other partial breech extraction	10D07Z5 Extraction of Products of Conception, High Forceps, Via Natural or Artificial Opening
	72.53 Total breech extraction with forceps to aftercoming head	
	72.54 Other total breech extraction	10D07Z6 Extraction of Products of Conception, Vacuum, Via Natural or Artificial Opening
	72.6 Forceps application to aftercoming head	
	72.71 Vacuum extraction with episiotomy	10D07Z7 Extraction of Products of Conception, Internal Version, Via Natural or Artificial Opening
	72.79 Other vacuum extraction	
	72.8 Other specified instrumental delivery	10D07Z8 Extraction of Products of Conception, Other, Via Natural or Artificial Opening
	72.9 Unspecified instrumental delivery	
	73.22 Internal and combined version with extraction	10E0XZZ Delivery of Products of Conception, External Approach
	73.59 Other manually assisted delivery	
	73.6 Episiotomy	
	74.0 Classical cesarean section	
	74.1 Low cervical cesarean section	
	74.2 Extraperitoneal cesarean section	
	74.4 Cesarean section of other specified type	
	74.99 Other cesarean section of unspecified type	

ICD-09-CM, International Classification of Diseases Ninth Revision Clinical Modification; ICD-10-CM/PCS, International Classification of Diseases Tenth edition, Clinical Modification/Procedure Coding System.

Table 2
Episodes and percentages of delivery identification elements, from January 2010 to December 2018.

Delivery Identification Elements	2010	2011	2012	2013	2014	2015	2016	2017	2018
Outcome of delivery[a], n (%)	83,261 (96.2)	79,897 (96.2)	74,089 (96.3)	67,204 (96.5)	65,299 (96.5)	67,903 (96.5)	71,050 (95.6)	70,068 (94.4)	67,710 (95.1)
Normal delivery[a], n (%)	15,715 (18.2)	15,222 (18.3)	12,118 (15.7)	9497 (13.6)	8562 (12.7)	7562 (10.7)	8320 (11.2)	9247 (12.5)	8959 (12.6)
Diagnosis-related group (DRG) delivery codes, n (%)	86,264 (99.7)	82,812 (99.7)	76,722 (99.7)	69,441 (99.7)	67,310 (99.5)	69,921 (99.4)	74,033 (99.6)	73,741 (99.4)	70,668 (99.2)
Selected delivery related procedures, n (%)	83,310 (96.3)	79,982 (96.3)	74,087 (96.3)	67,261 (96.6)	65,278 (96.5)	68,020 (96.7)	71,152 (95.8)	58,651 (79,0)	56,599 (79.5)
Deliveries episodes identified using all the identification elements[b], n	86,545	83,079	76,959	69,657	67,653	70,351	74,299	74,209	71,226
Deliveries episodes identified between 2010 and 2017[c], n	528,543							NA	
Deliveries episodes identified between 2017 and 2018[d], n	NA							145,435	
National deliveries reported by the national statistics institute[e]	100,130	95,149	88,708	81,559	81,077	83,957	85,444	84,684	85,604

Percentages represent the number of delivery episodes within that element. The same individuals may have multiple codes represented in different elements. NA, not applicable.

[a] The primary and secondary diagnosis codes of the episode were taken into account for this analysis.

[b] Obstetric deliveries episodes among inpatient hospitalization identified using all the elements from the method developed by Kuklina et al. [9].

[c] According to the International Classification of Diseases Ninth Revision Clinical Modification.

[d] After transition to the International Classification of Diseases Tenth edition, Clinical Modification/Procedure Coding System.

[e] Number of deliveries in national hospitals (public and private) including the mainland and autonomous regions (i.e. Azores and Madeira islands). Information collected by Instituto Nacional de Estatística (Statistics Portugal).

of the identified episodes in 2018 and 99.7 % between 2010 and 2013. The outcome of delivery codes was the second most frequent identifier, ranging from 94.4 % (2017) to 96.5 % (2013–2015), followed by selected delivery-related procedures codes, ranging from 79.0 % (2017) to 96.7 % (2015).

3.2. Temporal trends and ICD transition effects

Fig. 1 illustrates temporal trends of hospital delivery episodes between 2010 and 2018 across the different identification elements. The immediate effect and the trend of change after the transition from the ICD-9-CM coding system to ICD-10-CM/PCS on episodes of delivery by identification elements are shown in Table 3. Considering delivery episodes identified using all the identification elements Fig. 1a), a decrease in delivery episodes from 2010 to 2013 was observed, with a stabilization between 2013 and 2014, followed by a slight increase until 2016, and a slight decrease during 2017 and 2018. The transition to ICD-10-CM/PCS showed no immediate change in the trend of delivery episodes (Fig. 1a).

Similar trends were observed for outcome of delivery codes (Fig. 1b) and DRG delivery codes (Fig. 1d), with no immediate change associated with the ICD-10-CM/PCS transition (Table 3). Normal delivery codes showed a decreasing trend from 2010 to 2016 (Fig. 1c), with a slight increase in the trend after the ICD-10-CM/PCS transition (β2 278.44, $p = 0.005$) (Table 3).

Selected delivery-related procedures showed a decreasing trend (Fig. 1e), with a significant decrease in the number of episodes identified immediately after the ICD-10-CM transition, from 17,435 episodes in the last quarter of 2016 to 14,004 in the first quarter of 2017 (β2 -2736.21, $p < 0.001$).

3.3. Prophet model forecast results

The Prophet modeling approach was used to adjust data and forecast the quarterly trends of hospital delivery episodes with and without the inclusion of the ICD-10 transition variable. Fig. 2 illustrates these trends by identification elements, showing the forecasted hospital delivery episodes both excluding and including the ICD-10 alteration variable. Table 4 presents the Root Mean Square Deviation (RMSE) values for models with and without the ICD-10 variable across different variables. Notably, the 'Procedures' variable showed remarkable improvement when including the ICD-10 variable (RMSE without ICD-10: 818.6171; RMSE with ICD-10: 487.2418).

Table 5 presents the Prophet model parameters. For most variables, the parameters k (growth rate) and m (offset) were similar between models with and without ICD-10, with slight variations. The sigma_obs parameter remained consistent across models, indicating similar model uncertainty. The inclusion of the ICD-10 variable improved model fit for most variables, as evidenced by the RMSE values, providing a more stable representation of underlying data trends and seasonality. While the ICD-10 transition impacted the forecast's growth dynamics, it did not drastically alter the fundamental patterns captured by the Prophet model.

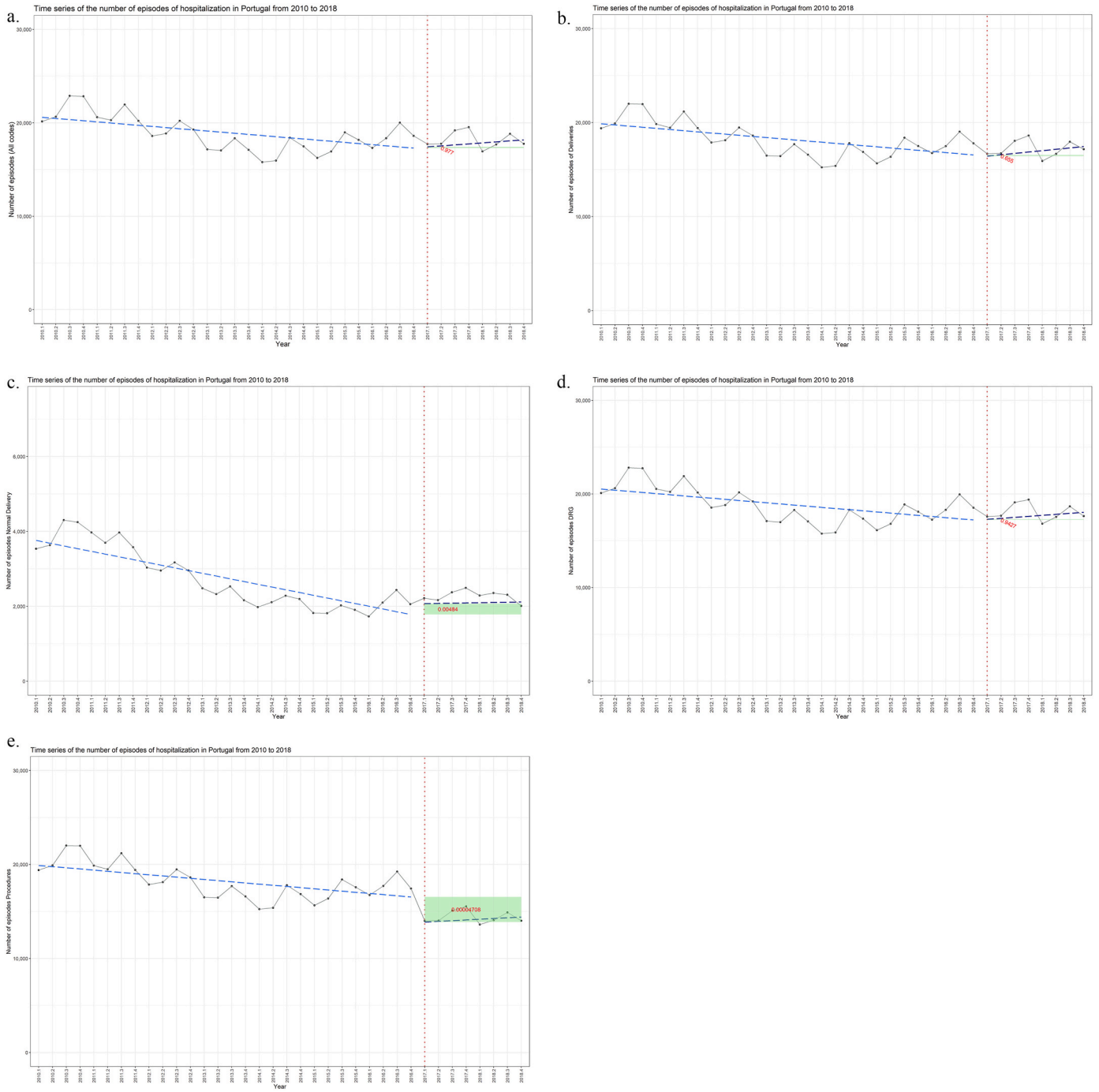

Fig. 1. Quarterly Trends of Hospital Delivery Episodes by Identification Elements. a. All elements of the delivery identification, b. Outcome of delivery codes; c. Normal delivery codes; d. Diagnosis-related group (DRG) delivery codes e. Selected delivery related procedures codes.
DRG, Diagnosis-related group.

Table 3
Effects of the transition of ICD-9-CM coding system to ICD-10-CM on episodes of delivery hospitalizations by delivery identification elements, from January 2010 to December 2018.

	Delivery episodes identified using all the identification elements	Outcome of delivery	Normal delivery	Diagnosis-related group (DRG) delivery codes	Selected delivery related procedures
Level of change immediately after ICD-10-CM/PCS transition, β_2	19.08 $p=$ *0.977*	−274.67 $p=$ *0.655*	278.44 $p=$ *0.005*	−47.34 $p=$ *0.943*	−2736.21 $p <$ *0.001*
Trend of change after ICD-10-CM/PCS transition, β_3	229.27 $p=$ *0.233*	267.51 $p=$ *0.112*	79.89 $p=$ *0.141*	230.43 $p=$ *0.230*	198.51 $p=$ *0.205*

ICD-10-CM/PCS, International Classification of Diseases Tenth edition, Clinical Modification/Procedure Coding System.

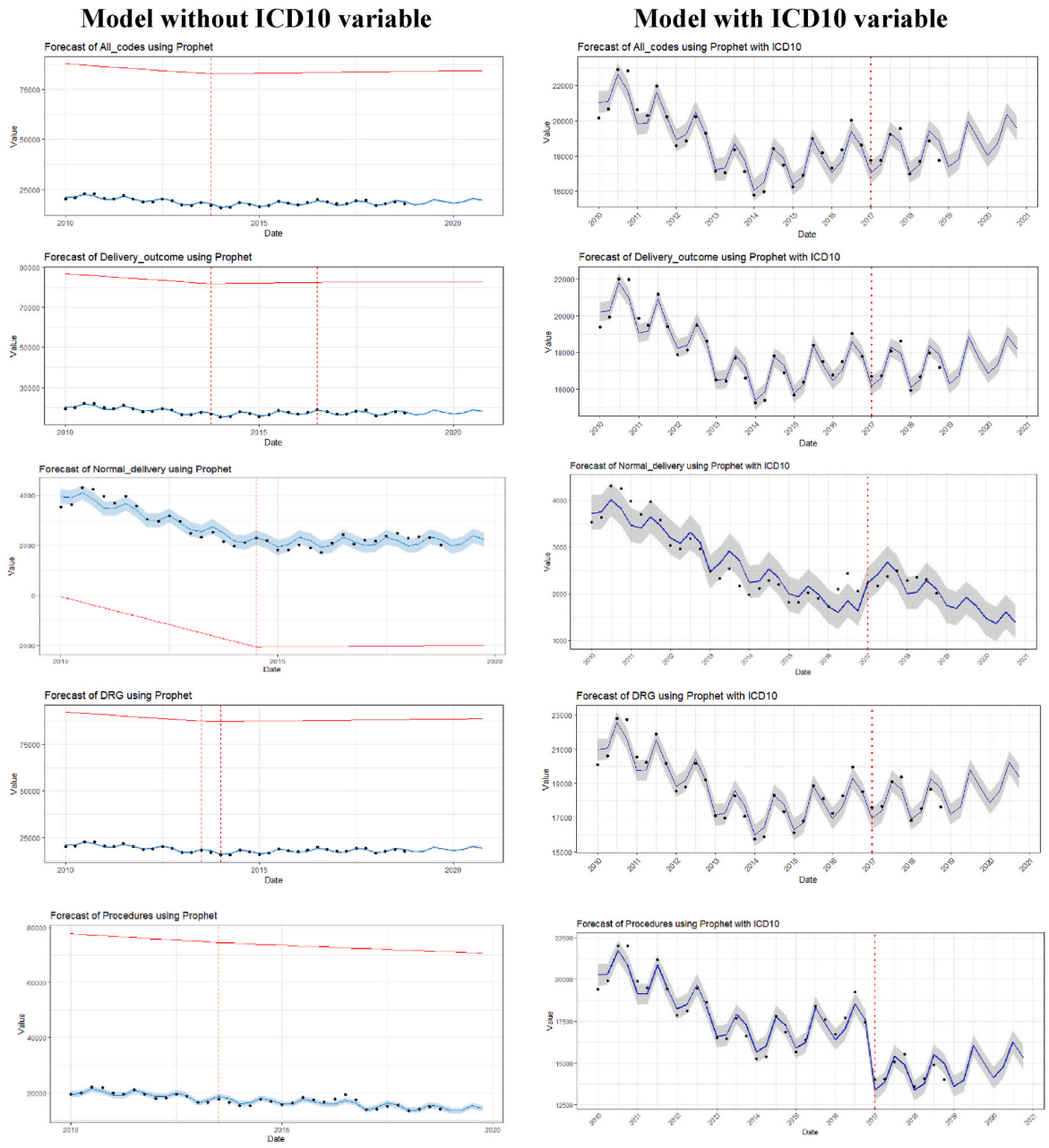

Fig. 2. Prophet modelling quarterly trends and forecasts of Hospital Delivery Episodes excluding and including ICD10 alteration variable by Identification Elements: All elements of the delivery identification, outcome of delivery codes; normal delivery codes; diagnosis-related group (DRG) delivery codes and selected delivery related procedures codes.
DRG, Diagnosis-related group; ICD-10, International Classification of Diseases Tenth edition.

Table 4
RMSE values for the model with and without the ICD-10 variable across different variables.

Variable	RMSE without ICD-10	RMSE with ICD-10
All_codes	479.4945	437.2668
Delivery_outcome	391.3872	415.2415
Normal_delivery	225.3638	278.7878
DRG	481.8946	478.0435
Procedures	818.6171	487.2418

DRG, Diagnosis-related group; ICD-10, International Classification of Diseases Tenth edition; RMSE, Root Mean Square Deviation.

Table 5
Prophet model Model Parameters.

Variable	k, growth rate (without ICD-10)	M, offset (without ICD-10)	sigma_obs (without ICD-10)	k, growth rate (with ICD-10)	m, offset (with ICD-10)	sigma_obs (With ICD-10)
All_codes	−0.5175359	3.85082	0.02092465	−0.5259021	4.016004	0.01911399
Delivery_outcome	−0.5213374	3.936446	0.01778625	−0.522931	4.211931	0.0188757
Normal_delivery	−0.909056	−0.01082073	0.05238282	−0.7508412	1.30801	0.06491032
DRG	−0.5309159	4.048216	0.02111926	−0.5171235	4.049530	0.02097646
Procedures	−0.3646574	3.528164	0.03718814	−0.5071361	3.928307	0.0221331

ICD-10, International Classification of Diseases Tenth edition; DRG, Diagnosis-related group.

4. Discussion

This study successfully applied the methodology developed by Kuklina et al. [9] to identify delivery episodes within the Portuguese National Hospital Discharge Database, providing valuable insights into delivery hospitalization trends from 2010 to 2018. Our findings demonstrate the robustness and reliability of this approach in tracking delivery hospitalizations longitudinally, even through the transition from ICD-9-CM to ICD-10-CM/PCS coding systems.

However, the episodes covered in this study come from a database with information from public hospitals, dependent on individual hospital units' reporting, and do not cover deliveries in the private sector or home births. Therefore, the contrast between the national estimates and our findings should be interpreted in this context.

During the study period, most delivery episodes were identified using the DRG delivery codes, although the other elements used to capture the episodes in this study, such as primary and secondary diagnoses and procedures, contribute to the derivation of the DRG itself [12,13].

The impact of the coding system transition has been assessed for several conditions, and changes in the incidence or prevalence of disease have been found after the coding change[19–21]. The transition of the coding system in Portugal from ICD-9-CM to ICD-10-CM, which came into effect at the beginning of 2017, generally had a small impact on the trends in the delivery episodes captured in the hospital discharge database. However, immediately after the coding system transition there was an increase in the number of episodes captured by diagnosis codes corresponding to normal delivery and a decrease in the number of episodes captured by selected delivery-related procedure codes.

One of the main aims of ICD-10-CM/PCS was to improve specificity [22], which may be related to the increase in the number of codes considered for normal delivery after the transition in our study, whereas ICD-10-CM codes represent an encounter for delivery with more detailed description and extended concepts for the type of delivery. A number of changes in the coding process for procedures may also have contributed to the significant reduction in the number of procedure codes recorded after the transition: diagnosis and procedure codes have been moved from the same list to independent lists; moving from a fixed procedure code to a constructed code of combined digits; the significant increase in the number of possible codes, from 3882 to 71,974; and the change in the structure of the code itself to allow for seven digits instead of the previous maximum of five digits [22]. Additionally, certain conditions are no longer recognizable in the ICD-10-CM/PCS coding system (e.g., breech delivery), and more than 95 % of codes are found to have only an approximate translation from ICD-9-CM codes to a relevant ICD-10-CM/PCS code [23].

All these changes had to be implemented during the transitional period. A study by Sand et al. [24] found that coders with experience in ICD-9-CM were better at transferring their knowledge to the process of coding diagnoses than to procedures.

Our analysis revealed several key trends in delivery hospitalizations. We observed an initial decline in delivery episodes from 2010 to 2013, followed by a period of stabilization in 2013–2014, and a subsequent modest increase from 2014 to 2016. A slight decrease was noted during 2017 and 2018. The transition from ICD-9-CM to ICD-10-CM/PCS in 2017 appeared to have varying impacts on different aspects of delivery episode identification.

The Prophet modeling approach provided additional insights into the impact of the ICD-10 transition. While the inclusion of the ICD-10 variable improved model fit for most variables, as evidenced by the RMSE values, the most remarkable change was observed in the 'Procedures' variable. The RMSE for this variable decreased substantially from 818.6171 without the ICD-10 variable to 487.2418 with its inclusion, indicating a significant improvement in model performance. This improvement in the 'Procedures' variable aligns with our initial findings of a significant decrease in the number of episodes identified by selected delivery-related procedures immediately after the ICD-10-CM/PCS transition. The Prophet model's better performance when accounting for the ICD-10 transition suggests that this change had a substantial impact on how procedures were coded and captured in the database.

For other variables such as overall delivery episodes, outcome of delivery, and DRG delivery codes, the Prophet model showed minimal differences between versions with and without the ICD-10 variable. This corroborates our initial observation that the transition had a smaller impact on these aspects of delivery episode identification.

The impact of the coding system transition has been assessed for several conditions, and changes in the incidence or prevalence of disease have been found after the coding change. In our study, the transition generally had a small impact on the overall trends in the delivery episodes captured in the hospital discharge database, but a substantial impact on procedure coding.

4.1. Strength and limitations

This study's main strength lies in its comprehensive assessment of delivery discharge episodes from public hospitals, providing an important national landscape over several years. To our knowledge, this is the first national study to use the Kuklina et al. method [9] to identify delivery episodes and study the trends and changes associated with the ICD coding system transition. The addition of the Prophet modeling approach further strengthens our analysis by providing a robust method for forecasting trends and evaluating the impact of the ICD-10 transition.

Nevertheless, several potential limitations should be noted. The database excludes data from private hospitals, accounting for 30 % of Portugal's total hospitalization episodes and inpatient admissions (e.g., emergency department visits) [6]. This exclusion may limit the generalizability of our findings to the entire Portuguese healthcare system. Data from hospitals in the autonomous regions of Portugal, namely the islands of Madeira and the Azores, have limited availability in this data source, potentially under-representing these regions [25].

The process of capturing the episodes' occurrence was based exclusively on the extraction of the diagnosis and procedure codes, which relies on the accuracy of the coding activity by the coding professionals and hospitals in reporting timely and accurate information. Thus, coding errors cannot be ruled out, and these could potentially affect our results, especially in the context of the ICD transition.

While the Prophet model provided valuable insights, it's important to note that like all forecasting models, it has inherent limitations. The model assumes that historical patterns will continue into the future,

which may not always be the case, especially in the dynamic field of healthcare.

Lastly, our study focused primarily on the quantitative aspects of delivery hospitalizations and the impact of the coding transition. We did not analyze qualitative changes in care or outcomes, which could provide additional context to our findings. For example, in 2017, the informatics system used to record coding activity was updated [26]. Second, potential differences in the demographics or health conditions of the population were not considered for this analysis.

Despite these limitations, this study provides a robust analysis of delivery hospitalization trends in Portugal and offers important insights into the effects of the ICD coding transition on healthcare data analysis.

5. Conclusions

Our investigation successfully applied the methodology developed by Kuklina et al. [9] and Prophet modeling to identify and analyze delivery episodes within the Portuguese National Hospital Discharge Database. The findings demonstrate the approach's reliability in tracking delivery hospitalizations longitudinally, while also highlighting the specific impacts of the transition from ICD-9-CM to ICD-10-CM/PCS coding systems.

Our analysis elucidated several key trends in delivery hospitalizations between 2010 and 2018. We observed an initial decline in delivery episodes from 2010 to 2013, followed by a period of stabilization in 2013–2014, and a subsequent modest increase from 2014 to 2016. A slight decrease was noted during 2017 and 2018. Notably, the transition from ICD-9-CM to ICD-10-CM/PCS in 2017 appeared to have minimal overall impact on the trends of delivery episodes. No significant immediate change was observed in trends for delivery episodes identified by outcome of delivery codes or DRG delivery codes post-transition. However, an increase in the trend of episodes identified by normal delivery codes was observed following the transition, and a significant decrease was noted in the number of episodes identified by selected delivery-related procedures immediately after the ICD-10-CM/PCS transition.

The study provides valuable insights into the trends of delivery hospitalizations in Portugal and the effects of a major coding system transition, particularly its substantial impact on procedure coding. The Prophet model results underscore the importance of considering coding system changes in time series analyses of healthcare data. These findings have important implications for health policy decisions, maternal health surveillance, and future studies on the impact of administrative data changes on healthcare research and quality assessment.

6. Future directions

Further research should aim to incorporate data from private hospitals to provide a more comprehensive national overview of delivery hospitalizations. It is also imperative to continuously monitor and validate the accuracy of coding practices, especially for procedures, to ensure the reliability of health data used for research and policy-making. Additionally, exploring the implications of coding changes on other health outcomes and addressing the identified limitations would further enhance our understanding of the impact of administrative data changes on healthcare research and quality assessment. The successful application of the Prophet model in this study also suggests its potential utility in analyzing and forecasting trends in other areas of healthcare data, particularly when accounting for significant systemic changes like coding transitions.

CRediT authorship contribution statement

Catarina de Paraíso Camarinha: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Maria Miguel Gomes Oliveira:** Writing – review & editing, Formal analysis. **Cecília Elias:** Writing – review & editing. **Miguel de Araújo Nobre:** Writing – review & editing. **Leonor Bacelar Costa Nicolau:** Writing – review & editing. **Cristina Furtado:** Writing – review & editing. **Andreia Silva da Costa:** Writing – review & editing. **Paulo Jorge da Silva Nogueira:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis.

Ethical statement

This study utilizes morbidity and hospital admissions data provided by the Central Administration of the Health System (ACSS) under a formal protocol with the Faculty of Medicine, University of Lisbon (FMUL). The data were anonymized by ACSS prior to access, ensuring compliance with national and European data protection regulations, including The General Data Protection Regulation (GDPR).

The study adheres to ethical principles for medical research, maintaining strict confidentiality and data security. No direct contact or primary collection of individual data occurred and no linkage with other personal data sources was performed. All analyses were conducted on de-identified data, reported in aggregate form, with no possibility of re-identification. The data used was strictly limited to the research objectives of this study.

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Declaration of competing interest

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.imu.2025.101626.

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