

Original Article

Maternal admissions to intensive care units in France: Trends in rates, causes and severity from 2010 to 2014



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ARTICLE INFO

Article history:

Available online 21 December 2018

Keywords:

Obstetric admissions
Intensive care unit
Pregnancy
Hospital discharge database
Prevalence
Trends
Regional disparities

ABSTRACT

Introduction: Maternal intensive care unit admission is an indicator of severe maternal morbidity. The objective of this study was to estimate rates of maternal intensive care unit admission during or following pregnancy in France, and to describe the characteristics of women concerned, the severity of their condition, associated diagnoses, regional disparities, and temporal trends between 2010 and 2014. **Methods:** Women hospitalised in France in intensive care units during pregnancy or up to 42 days after pregnancy between January 2010 and December 2014 were identified using the national hospital discharge database (PMSI-MCO). Trends in incidence rates were quantified using percentages of average annual variation based on a Poisson regression model.

Results: In total, 16,011 women were admitted to intensive care units, representing an overall incidence of 3.97‰ deliveries. This number decreased significantly by 1.7% on average per year. For women who gave birth (60.5% by C-section), 62.5% of admissions occurred during their hospitalisation for delivery. The SAPS II score, an indicator of severity, significantly increased from 18.4 in 2010 to 21.5 in 2014. Obstetrical haemorrhage (39.8%) and hypertensive complications during pregnancy (24.8%) were the most common reasons for admission. In mainland France, the Ile-de-France (i.e., greater Paris) region had the highest rates of intensive care units admission (5.05‰) while the Pays-de-la-Loire region had the lowest (2.69‰).

Conclusion: The rate of maternal intensive care unit admission decreased from 2010 to 2014 in France, with a concomitant increase in case severity. In-depth studies are needed to understand the territorial disparities identified.

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1. Introduction

Although pregnancy and childbirth are generally healthy events, they nevertheless can be in some cases associated with maternal complications that can worsen and lead to maternal death [1,2]. In developed countries, a shift has been observed over the last few decades in the profiles of mothers and obstetrical practices [3]. More specifically, women become pregnant for the

first time at an older age. Furthermore, the prevalence of pregnant women who are obese or who have other chronic conditions prior to pregnancy has increased, as have the rates of induced labour and caesarean deliveries [3–6]. Although these changes increase the risk of complications, their effects on the health of mothers are not yet well understood, justifying the need to monitor maternal health using recognised health indicators. A definition of maternal near miss has been proposed by the WHO, but its relevance for high-resource countries is questionable [7]. In the absence of a consensual international definition for severe acute maternal morbidity (SAMM), maternal admission to intensive care units (ICU) has been considered by many authors as a “proxy” for reasonably assessing SAMM [8–16].

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In the international literature, very few studies examining maternal ICU admission (i.e., analysing women's characteristics profiles and the causes for admission) have been conducted at a national level. In the Netherlands, a national study based on ICU admissions during and after pregnancy showed an incidence of 2.4 per 1000 births between 2004 and 2006 [16]. An American study conducted in the state of Maryland also revealed an ICU admission rate of 2.4‰ births, this incidence remaining stable over the 1999–2008 period [14].

In France, few related studies have been published. Some were conducted at the regional level and others were based on hospital surveys [17–19]. One study at the national level using hospital discharge data from the Medicalisation Programme for Information Systems for Medicine, Surgery, and Obstetrics (PMSI-MCO) estimated an incidence of maternal ICU admission of 3.9‰ births in 2006 which decreased significantly to 3.4‰ births in 2009 [20]. Since these results, the algorithm used to identify maternal admissions to the ICU has been improved, making it now possible to also include women for whom a code mentioning pregnancy or postpartum state has been omitted.

Accordingly, the primary objective of the study was to assess, on the basis of the improved algorithm, the rate of maternal ICU admissions in France, the characteristics of the women concerned, the causes for admission and the severity of the cases, as well as associated trends over a 5-year period (2010 to 2014). The secondary objective was to assess potential regional disparities.

2. Materials and methods

2.1. Data source

The ICU admissions analysed in this study were extracted from the PMSI-MCO national hospital discharge database. This exhaustive database provides information on the hospital stays of all patients hospitalised in France. Diagnoses are coded according to the International Classification of Diseases, 10th revision (ICD-10) [21] and procedures are coded in accordance with the French Common Classification of Medical Procedures (CCAM). A previous study showed the validity of the coding of maternal ICU admissions in this database [22].

2.2. Study population

The study population comprised women aged 14 to 50 years hospitalised in an ICU in French territory (i.e., mainland France and its overseas regions (*Départements et Régions d'Outre-mer*) (Guadeloupe, Martinique, French Guiana, Reunion and Mayotte) between January 2010 and December 2014, during pregnancy or in the 42 days after pregnancy, irrespective of its outcome (i.e., birth or early termination due to miscarriage, extra-uterine pregnancy, or abortion).

2.3. Identification algorithms

In order to identify both maternal ICU admissions mentioning the gravidopuerperal state during the ICU stay, and those where this information had been omitted, we applied two algorithms for identifying ICU stays, presented in Fig. 1 and described in Appendix 1. ICU admissions were identified by SUPSTF or SUPREA codes which indicated that the woman had spent at least one day in a unit authorised to administer intensive care. We then linked all stays for a given patient for a given year in order to account for the number of women, irrespective of the number of stays.

In order to retain only maternal ICU admissions directly related to pregnancy, we excluded ICU admissions for cancer (ICD-10,

chapter C) and those for trauma, an accident, or suicide attempt, when the main diagnosis for the stay did not mention the gravidopuerperal state (Appendix 2).

2.4. Variables analysed

The following maternal characteristics were studied: age at admission, type of pregnancy (e.g., multiple or single) and mode of delivery (e.g., vaginal or caesarean section) for women who gave birth (Appendix 1). The characteristics of ICU stays studied were: gestational age upon admission (i.e., when ICU admission occurred during pregnancy or during hospitalisation for delivery), and the time interval between delivery and admission to the ICU in patients admitted after leaving the maternity ward in the same hospital or after transfer to another hospital. The severity of cases was assessed using three markers in the PMSI-MCO database as follows: the length of the ICU stay, the SAPS II Score (Simplified Acute Physiology Score II) [23] and maternal mortality.

Causes of maternal ICU admissions were described based on the diagnosis codes reported in the database as the main and the ten first secondary diagnoses. The algorithm for selecting codes is described in Appendix 3. Complications during the first trimester were studied globally. The patient's region of residence was determined based on geographic residency codes, while ICU hospitalisation regions were based on hospitals' geographic codes.

Finally, data from the Annual Statistical Survey of Healthcare institutions (*Statistique Annuelle des Etablissements de Santé* (SAE) in French) survey was used to describe the link between maternal ICU incidence rate and the availability of intensive care services.

2.5. Statistical analyses

The incidence of maternal ICU admission was first estimated for the whole country, then separately for mainland France and overseas regions before finally being calculated at the regional level. These rates were calculated as the ratio between the number of women admitted to the ICU and the number of deliveries reported in the PMSI-MCO. Rates were expressed per 1000 deliveries and their 95% confidence intervals calculated. Regional incidence rates were standardised for mother's age at delivery. For these analyses, the reference population was women who delivered throughout the whole of France territory in 2010 (source: PMSI-MCO). The rates calculated using the region of residence were very close to those calculated based on the region of hospitalisation suggesting few transfers between regions. Therefore, in order to characterise territorial inequalities in maternal admission to the ICU, only rates calculated based on region of residence were presented since the region of residence more accurately reflects women's living conditions.

Trends for incidence rates and their confidence intervals from 2010 through 2014 were quantified by the percentage of the average annual variation, estimated using a Poisson regression with the logarithm of the annual rate of incidence as the dependent variable and the year as the independent variable.

The characteristics of women were described in percentages for categorical variables, and in averages and medians for continuous variables. Changes in characteristics during the period were estimated using Cochran-Armitage trend tests for categorical variables and ANOVA tests for continuous variables.

The distribution of the causes of maternal ICU admissions were analysed for each year and changes between 2010 and 2014 were estimated using the Cochran-Armitage linear trend test. These distributions were calculated using the ratio between the number of women per each pathology group and the number of women admitted to the ICU, excluding admissions during the first trimester of pregnancy. We also performed an additional analysis

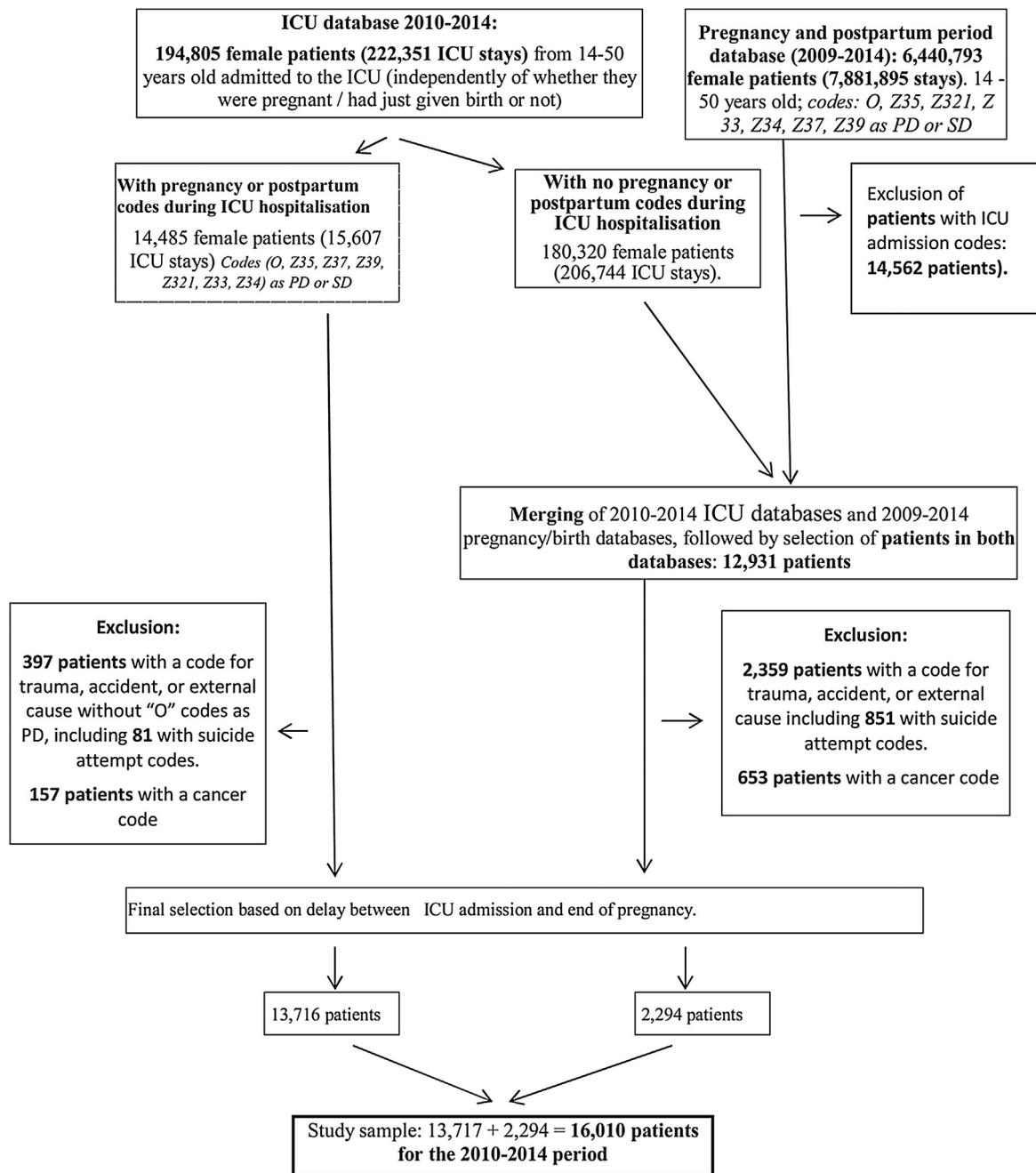


Fig. 1. Selection steps for patients admitted to an ICU during or after (i.e., within 42 days) pregnancy, 2010–2014.

to assess maternal high-dependency units (HDU) admissions separately in 2010–2014 period. These rates were calculated as the ratio between the number of women admitted to the HDU and the number of deliveries reported in the PMSI-MCO and trends were quantified by the percentage of the average annual variation, estimated using a Poisson regression.

The significance level retained was 5%. Statistical analyses were conducted using SAS Enterprise Guide software, version 7.1® (SAS Institute Inc., Cary, NC, USA).

3. Results

Between 2010 and 2014, 4,030,409 deliveries were recorded in France. A total of 16,010 women were admitted to an ICU during

pregnancy, delivery or the postpartum period. Therefore, the overall incidence rate was 3.97 per 1,000 deliveries, which decreased significantly during the study period (annual decrease -1.72% (95% CI: $[-2.00\%; -1.45\%]$; $P < 0.0001$), from 4.10 to 3.83 per 1000 deliveries (Fig. 2).

Concomitantly, the 2010–2014, 5-year rate of maternal HDU admissions was 2.62 per 1,000 deliveries. Unlike ICU admissions, the maternal HDU admissions rate increased significantly during the study period from 1.91 to 3.58 per 1,000 deliveries (Fig. 3).

Between 2010–2014, maternal age was on average 30.7 years and significantly increased, from 30.5 years in 2010 to 31.0 in 2014 ($P = 0.007$) (Table 1). Among women who gave birth and for whom information on the type of pregnancy was available (87.3%), 8.1% had a multiple pregnancy. This proportion remained stable over the study period. Among those who gave birth and for whom

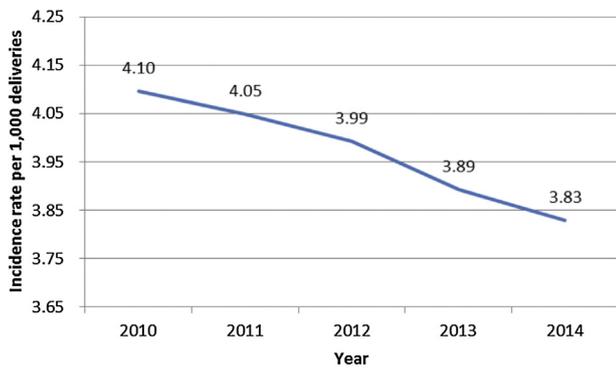


Fig. 2. Crude rates of maternal ICU admissions per 1000 deliveries, 2010–2014, all of France territory.

information on the mode of delivery was available (87.1%), 60.5% had a caesarean section. This proportion also remained stable over the study period. Early pregnancy termination occurred in 8.3% of women admitted to an ICU during or after pregnancy as follows: 32.3% ($n = 390$) – extra-uterine pregnancy, 32.0% ($n = 387$) – medically-induced abortion, 20.8% ($n = 251$) – miscarriage and 14.9% ($n = 180$) – unspecified cause (data not presented).

Among women who gave birth, most were admitted to the ICU during their hospitalisation for childbirth (68.2%). This analysis did not specify whether admission occurred just before or just after birth. Sixteen point seven percent were admitted during pregnancy while 15.1% were admitted subsequent to their discharge from hospital after delivery (data not presented). The average gestational age of pregnancy for women admitted during pregnancy was 34.9 weeks of amenorrhoea (WA), while that of women admitted during their hospitalisation for delivery was 35.6 WA. Women admitted subsequent to their discharge from hospital were admitted on average 11.1 days after delivery. This delay increased significantly between 2010 and 2014 ($P < 0.0001$). The severity of cases increased over the study period with a significant increase in the average SAPS II score from 18.4 in 2010 to 21.5 in 2014 ($P = 0.008$) (Table 1). Finally, 208 deaths occurred among maternal ICU admissions (1, 3%), which corresponds to a case fatality rate of 1 in 77 (Table 1). No temporal trend was identified for mortality between 2010 and 2014 (Table 1).

The main causes of maternal ICU admission beyond the first trimester of pregnancy were obstetrical haemorrhage (39.8%), hypertensive complications during pregnancy (24.8%), and cardiac or circulatory complications (11.3%) (Table 2). Women could have had more than one complication. However, renal, neurological, and hepatic dysfunctions were very rarely observed ($< 1\%$, each). Furthermore, approximately 14% presented various diagnoses that did not fit into any of the categories mentioned above. The most

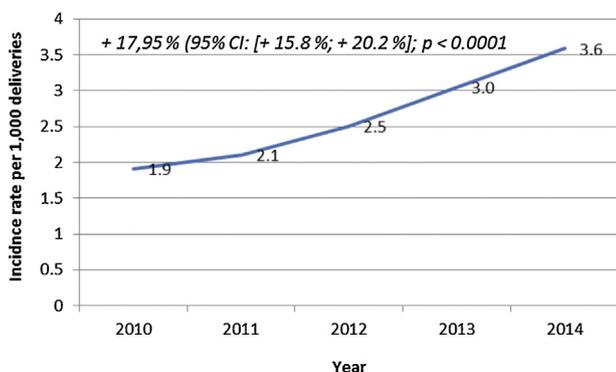


Fig. 3. Crude rates of maternal HDU admission per 1000 deliveries, 2010–2014, all of French territory HDU: high-dependency units.

severe clinical conditions were observed in patients with the least frequent reasons for admission (with an average SAPS II Score of 43.8 in women with amniotic embolisms) while the least severe clinical conditions states were related to the most common reasons for admission (with an average SAPS II Score of 19.3 and 21.1 for patients with hypertensive complications and obstetrical haemorrhage, respectively) (data not presented).

We observed a significant increase in the proportion of cerebrovascular and cardio-circulatory complications during the five-year study period, ($P < 0.001$ and $P = 0.01$, respectively), whereas the proportion of obstetrical haemorrhage, hypertensive complications, and complications from anaesthesia significantly decreased (Table 2).

With regard to regional analyses, maternal ICU admission rates standardised for age were comparable with raw rates (Table 3). From 2010 to 2014, French overseas regions had the highest admission rates (5.36 vs. 3.91‰ in mainland France). In mainland France, the Ile-de-France and Hauts-de-France regions reported the highest incidence rates (5.05 and 4.29‰, respectively) while the Pays-de-la-Loire and Bretagne regions had the lowest (2.69 and 2.74‰, respectively). Trend analyses showed a significant decrease in maternal ICU admission rates in Ile-de-France and Nouvelle Aquitaine (all $P < 0.001$), while the incidence increased significantly in the Hauts-de-France region ($P < 0.001$).

As for regional differences in the reasons for admission, obstetrical haemorrhage were the main cause of maternal ICU admission in all regions except the Grand-Est and in some overseas regions, where hypertensive complications were more common (Grand-Est 32.6% and 30.8%, respectively; French Guiana: 49.1% vs. 38.6%; Martinique: 37.0% vs. 34.0%; Mayotte: 40.7% vs. 32.7%) (data not presented).

4. Discussion

Between 2010 and 2014, approximately 16,000 women who were pregnant or had just given birth were admitted to ICU in France for an overall incidence of 3.9 per 1,000 deliveries. This incidence rate significantly decreased over the study period, while clinical severity increased.

The incidence rate observed in France for the study period is consistent with the estimations presented by international reviews [10–12,15]. More recently, a population-based study reported an ICU admission incidence rate of 4.2‰ in Maryland in the USA [14], very close to that in France, whereas rates were considerably higher in New Jersey (15.4 per 1000 deliveries from 1997 to 2005) [9], and Texas (39.0 per 1000 deliveries from 2001 to 2010) [24].

The significant decrease we found over the study period in the incidence of maternal ICU admission is consistent with trends shown in a previous French study conducted between 2006 and 2009 on the same database [20]. ICU admission depends on several factors, including the organisation of the health care system and the accessibility and availability of beds in ICU. This has been shown by Chantry et al. [20] and by examination of the data from the SAE survey [25]. Despite the decrease in the rate of maternal ICU admissions, mothers presented more severe clinical conditions, which more often require resuscitation procedures and techniques provided in ICU.

It is possible that the decreasing incidence of maternal ICU admissions observed in our study was partly due to organisational changes in France. More specifically, the number of HDU/intermediate care units (units where women either have no organ dysfunction or in whom organ dysfunction is not severe to require organ replacement) has increased over the last two decades, and our additional analysis showed an increasing rate of maternal

Table 1

Characteristics of maternal ICU admissions and changes over the 2010–2014 period, all of France territory.

Characteristics	Total	2010	2011	2012	2013	2014	P-trend
	(n = 16,010)	(n = 3361)	(n = 3281)	(n = 3220)	(n = 3099)	(n = 3049)	
Average age (±sd)	30.7 (± 6.1)	30.5 (± 6.1)	30.6 (± 6.0)	30.7 (± 6.1)	30.8 (± 6.1)	31 (± 6.0)	0.007
Multiple pregnancy [n (%)]	946 (8.1)	197 (7.5)	234 (9.0)	202 (9.1)	153 (7.3)	160 (7.7)	0.61
Pregnancy outcome							0.02
Early termination (during 1st trimester) [n (%)]	1208 (8.3)	238 (7.9)	225 (7.5)	242 (9.3)	249 (8.9)	255 (9.1)	
Birth	13,331 (91.7)	2790 (92.1)	2775 (92.5)	2,679 (91.7)	2,543 (91.1)	2,544 (90.9)	
Birth via Caesarean delivery (as a percentage of women who gave birth) [n (%)]	7024/ 11,617 (60.5)	1632/ 2664 (61.7)	1529/ 2600 (58.8)	1332/ 2224 (59.9)	1294/ 2076 (62.3)	1237/ 2073 (59.7)	0.81
Average gestational age upon admission if admission was pre-partum (WA ± SD)	34.9 (± 7.0)	36.4 (± 6.0)	35.4 (± 6.1)	33.8 (± 7.5)	34.3 (± 7.7)	34.8 (± 7.0)	0.004
median [Q1–Q3]	38 [33–39]	39 [36–40]	38 [33–39]	37 [30–39]	38 [31–40]	38 [33–39]	
Average gestational age upon admission if admission was during hospitalisation for delivery (WA ± SD)	35.6 (± 4.5)	35.5 (± 4.5)	35.7 (± 4.5)	35.6 (± 4.5)	35.7 (± 4.4)	35.9 (± 4.5)	0.19
median [Q1–Q3]	37 [33–39]	37 [33–39]	37 [33–39]	37 [33–39]	37 [33–39]	37 [34–39]	
Average delay between admission to ICU and birth if admission was after discharge following hospitalisation for delivery (days) (±sd)	11.1 (±10.9)	8.5 (± 10.2)	9.9 (± 10.8)	12.6 (± 11.2)	13.1 (± 11.0)	14 (± 10.7)	< 0.0001
median [Q1– Q3]	7 [2–17]	3 [1–13]	6 [1–14]	9 [3–20]	11 [4–19]	10.5 [6–21]	
Average duration of stay in ICU	3.1 (± 5.5)	3 (± 5.6)	3.1 (± 6.4)	3 (± 4.8)	3 (± 4.5)	3.1 (± 5.9)	0.66
median [Q1–Q3]	2 [1–3]	2 [1–3]	2 [1–3]	2 [1–3]	2 [1–3]	2 [1–3]	
Average SAPS II Score (±sd)	20.5 (± 17.9)	20.7 (± 18.4)	19.5 (± 13.8)	20.3 (± 14.3)	20.97 (± 14.0)	21.5 (± 26.7)	0.008
Mortality	208 (1.3%)	40 (1.19%)	43 (1.31%)	45 (1.40%)	41 (1.32 %)	39 (1.28%)	0.75

WA: weeks of amenorrhoea; SAPS II: severity is correlated with high scores.

admission in these units over time. This could partly explain the decrease in the maternal ICU admissions rate observed in our study. However, the much greater increase seen in HDU admissions suggests that these newly opened units attract more women than would have previously been admitted to ICU, in particular women who previously would have stayed in the recovery rooms or on the labour wards for surveillance purposes. In our study, in order to compare our results with the international literature, we used the most common definition for ICU admission, which does not include HDU admissions [16]. In addition, to our knowledge, unlike for ICU admissions, to date no study has assessed the validity of the coding of HDU admission of pregnant women in the PMSI-MCO database, limiting its potential usefulness. Additional studies could be performed to better understand

the characteristics of patients admitted to these units, the reasons for admission, and the severity of each case.

Just as in the international literature, we found that most women admitted to an ICU during their hospitalisation for delivery or during the postpartum period had given birth via caesarean delivery. Moreover, the preponderance of obstetrical haemorrhage and hypertensive complications as causes of admission is also found in the literature [8,14,16,18,20,24]. We were able to study the changing dynamics, showing that the proportions of these two groups are decreasing. Furthermore, just as in the study by Wanderer et al., our analyses showed a decrease in the proportion of complications arising from anaesthesia [14]. Conversely, we found that the proportion of cerebro-vascular, cardiac, and circulatory complications tended to increase during the study

Table 2

Distribution of reasons for maternal ICU admissions and changes over the 2010–2014 period, over all French territory.

	Total		2010		2011		2012		2013		2014		P-trend
	(n = 16,010)		(n = 3361)		(n = 3281)		(n = 3220)		(n = 3099)		(n = 3049)		
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
Complications during the 1st trimester	877	(5.5)	177	(5.3)	181	(5.5)	174	(5.4)	180	(5.8)	165	(5.4)	0.64
Obstetrical haemorrhage ^a	6,016	(39.8)	1325	(41.6)	1259	(40.6)	1245	(40.9)	1120	(38.4)	1067	(37.0)	0.0001
Hypertensive complication during pregnancy ^a	3,753	(24.8)	833	(26.2)	764	(24.7)	759	(24.9)	734	(25.2)	663	(23.0)	0.02
Cerebro-vascular condition ^a	888	(5.9)	144	(4.5)	182	(5.9)	187	(6.1)	185	(6.3)	190	(6.6)	0.001
Pulmonary embolism and thrombotic disorder ^a	709	(4.7)	151	(4.7)	136	(4.4)	141	(4.6)	144	(4.9)	137	(4.8)	0.65
Complication from anaesthesia ^a	156	(1.0)	42	(1.3)	33	(1.1)	32	(1.1)	25	(0.9)	24	(0.8)	0.04
Amniotic fluid embolism ^a	105	(0.7)	22	(0.7)	16	(0.5)	23	(0.8)	23	(0.8)	21	(0.7)	0.47
Cardiac and circulatory condition ^b	1714	(11.3)	316	(9.9)	339	(10.9)	363	(11.9)	379	(13.0)	317	(11.0)	0.01
Infection ^b	1256	(8.3)	261	(8.2)	267	(8.6)	245	(8.0)	231	(7.9)	252	(8.7)	0.82
Respiratory dysfunction ^b	689	(4.6)	129	(4.1)	166	(5.4)	131	(4.3)	115	(3.9)	148	(5.1)	0.53
Renal dysfunction ^b	151	(1.0)	32	(1.0)	33	(1.1)	32	(1.1)	26	(0.9)	28	(1.0)	0.68
Neurological dysfunction ^b	154	(1.0)	33	(1.0)	23	(0.7)	38	(1.3)	28	(1.0)	32	(1.1)	0.53
Hepatic dysfunction ^b	72	(0.5)	22	(0.7)	16	(0.5)	6	(0.2)	16	(0.6)	12	(0.4)	0.17
Other reason	2117	(14.0)	424	(13.3)	408	(13.2)	407	(13.4)	408	(14.0)	470	(16.3)	0.0009

^a Conditions in Group I detailed in Appendix 3.^b Conditions in Group II detailed in Appendix 3.

Table 3
Crude and standardised incidence rates (per 1000 deliveries) of maternal ICU admissions by region of residence and their changes, classified in descending order, 2010–2014.

Region of residence	Number of women admitted to ICU, 2010–2014	Number of deliveries, 2010–2014	Crude rate of maternal admissions to ICU 2010–2014	Rate standardised for age at delivery, 2010–2014	Average annual variation (%)	P for trend 2010–2014
All of France territory	15,923	4,008,781	3.96		–1.68	0.0001
Ile-de-France	4572	881,445	5.18	5.05 [4.90–5.20]	–6.24	0.0001
Hauts-de-France	1659	396,275	4.12	4.29 [4.09–4.50]	3.68	0.0007
Normandie	758	194,727	3.89	3.94 [3.65–4.22]	–0.51	0.83
Centre-Val de Loire	563	146,411	3.84	3.88 [3.56–4.20]	–2.32	0.52
Bourgogne-Franche-Comté	572	151,055	3.79	3.85 [3.54–4.17]	1.18	0.75
Corse	51	13,571	3.76	3.59 [2.60–4.59]	4.43	0.20
Grand Est	1158	309,623	3.74	3.81 [3.59–4.03]	–2.62	0.35
Nouvelle Aquitaine	1087	293,138	3.71	3.72 [3.50–3.94]	–4.17	0.0004
Auvergne-Rhône-Alpes	1618	464,137	3.49	3.53 [3.35–6.69]	–0.37	0.72
Provence-Alpes-Côte-D'Azur	976	290,073	3.36	3.34 [3.13–3.55]	1.27	0.63
Occitanie	982	308,618	3.18	3.17 [2.97–3.37]	1.98	0.33
Bretagne	488	178,935	2.71	2.74 [2.50–2.99]	6.36	0.07
Pays-de-la-Loire	580	220,332	2.63	2.69 [2.47–2.90]	0.89	0.61
Mainland France	15,064	3,848,340	3.91		–1.68	0.0001
Mayotte ^a	112	13,810	8.3	7.88 [6.36–9.40]	5.39	0.60
La Réunion	382	69,616	5.48	5.68 [5.08–6.27]	1.72	0.55
Martinique	116	22,004	5.27	4.96 [4.01–5.92]	–22.33	0.006
Guadeloupe	130	27,518	4.72	4.26 [3.48–5.04]	–3.67	0.39
Guyane	119	27,493	4.32	4.33 [3.48–5.20]	–4.41	0.58
Overseas regions	859	160,441	5.36		–2.36	0.32

^a Data from 2011 to 2014.

period. This fact could be explained by changes in pregnant women's profiles: women who become pregnant for the first time are now older. They are also more frequently obese and suffer from chronic conditions pre-dating pregnancy [3]. This temporal trend is also consistent with results of the raising cardiovascular related maternal mortality observed in the UK [26].

The results presented here should be compared with those from the latest National Confidential Enquiry into Maternal Deaths (ENCMM). In France, between 2001 and 2012, maternal mortality due to haemorrhage and hypertensive complications significantly decreased [27,28]. This has been attributed to a multidisciplinary effort to improve quality of care, notably by issuing recommendations for clinical practices and implementing actions to assess their integration.

With regard to regional disparities in maternal ICU admission, the highest rates in our study were found in French overseas regions, with Mayotte having the highest incidence of all. The latest ENCMM also showed that overseas regions have a higher maternal mortality rate (14%), despite only accounting for 4% of live births, the risk of maternal mortality being 4.5 times that of mainland France [27,28]. The Ile-de-France and Hauts-de-France regions had the highest maternal ICU admission incidence rates of all regions of mainland France. The ENCMM report also showed particularly high levels in Ile-de-France [27]. Standardisation for age showed that mothers' maternal age could not explain the observed differences in ICU admissions rates, particularly the high levels in Hauts-de-France. It should be noted that this region has relatively poor social indicators and high obesity rates [29]. The small increase (1.4%) in the number of ICU beds in this region [25] is probably insufficient to explain the 3.7% increase in the incidence of ICU admissions in the region. Conversely, in the overseas region of Martinique, which has the greatest average annual decrease in ICU admission incidence (–22%) [25], this decrease seemed to be directly linked to that in the health services offered, as highlighted by the SAE survey which showed a 16% decrease in the number of available beds from 2013 to 2014. Future studies should explore the mechanisms that could explain these regional differences, in order to describe the individual

characteristics of women and those of the health care system as has already been done for maternal mortality [30].

One of the strengths of this work, in terms of its originality, lies in the fact that we used standardised regional incidences, which allowed us to identify territorial disparities for the first time. Moreover, thanks to the SAPS II Score in the PMSI-MCO database – information rarely available in the international literature – it was easier to describe the evolution of the severity of cases. It is important to point out that SAPS II tends to overestimate mortality in obstetric patients [15] (partly explained by physiological changes associated with pregnancy), but is recognised by several authors to be a good discriminator [31,32]. Accordingly, as a marker of severity, this score is useful when identifying critically ill obstetric patients. Moreover, the availability of the continuous scoring of SAPS II for women admitted to ICU constitutes a unique worldwide opportunity to assess the severity of cases with an additional marker, despite the above-mentioned limits in its accuracy.

Another strength is the exhaustive coverage of hospitalisations across the entire French territory. The high numbers of cases included enabled us to estimate incidences and analyse changes over time for different sub-groups, notably maternal characteristics and reasons for ICU admission. Furthermore, we incorporated an improved algorithm for selecting cases, which made it possible to improve the exhaustiveness of identified cases in the PMSI-MCO. Unlike a French previous study [20], we were able to identify women admitted to the ICU during and after pregnancy, even when a code mentioning a context of pregnancy was omitted from the ICU admission stay coding. This difference may explain the gap between maternal ICU admission incidence rates in the two studies.

Apart from the above-mentioned drawback to using SAPS II, this study has other limitations that deserve mentioning. First, at the outset, the PMSI-MCO database was originally designed to describe hospital activities in medical and economic terms, not to be used as an epidemiological monitoring tool. For this reason, some maternal factors are lacking, such as sociodemographic information (e.g., socio-professional category, level of education, etc.), maternal

body-mass index, family medical history, and parity. Second, the lack of data on the geographic origin of the women limits international comparisons. A study in the Netherlands showed that the risk of ICU admission for women of non-Western origin was 1.4 times higher (95% CI: 1.2–1.7) than in women of Western origin [16]. Similarly, the lack of this information limits comparisons with the results of the French ENCMM, which showed a predominance of maternal mortality in non-French born women. For example, women from Sub-Saharan Africa had a 3.5 times greater risk of maternal mortality than women born in France [27]. Third, the quality of coding reasons for admission and for maternal mortality was sometimes suboptimal. Finally, the PMSI-MCO database version used to perform our study does not allow the separation of maternal ICU admissions before and after delivery when they occurred during the delivery stay. It is one of the inherent limitations of this database. More generally, more precise analyses of the exact sequence of stays in the complete PMSI database are complex. This work is currently being explored.

Admission rates are in part related to the available medical services. However, we analysed the results by integrating the numbers of beds available and changes in these numbers, in order to improve interpretations of the SAMM indicator.

5. Conclusion

Over the 2010–2014 period, the incidence of maternal ICU admission significantly decreased in France with a concomitant increase in the clinical severity of women admitted. Over the study period, although obstetrical haemorrhage followed by hypertensive complications were the two most common reasons for admission, their proportions decreased while those for cerebral and cardiovascular complications increased. Major regional disparities exist within mainland France and between mainland France and the country's overseas regions. An understanding of the mechanisms behind these differences is crucial.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at <https://doi.org/10.1016/j.accpm.2018.12.007>.

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