In-hospital mortality following lung cancer resection: nationwide administrative database

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ABSTRACT Our aim was to determine the effect of a national strategy for quality improvement in cancer management (the "Plan Cancer") according to time period and to assess the influence of type and volume of hospital activity on in-hospital mortality (IHM) within a large national cohort of patients operated on for lung cancer.

From January 2005 to December 2013, 76 235 patients were included in the French Administrative Database. Patient characteristics, hospital volume of activity and hospital type were analysed over three periods: 2005–2007, 2008–2010 and 2011–2013.

Global crude IHM was 3.9%: 4.3% during 2005–2007, 4% during 2008–2010 and 3.5% during 2011–2013 ($p<0.01$). 296, 259 and 209 centres performed pulmonary resections in 2005–2007, 2008–2010 and 2011–2013, respectively ($p<0.01$). The risk of death was higher in centres performing <13 resections per year than in centres performing >43 resections per year (adjusted (a)OR 1.48, 95% CI 1.197–1.834). The risk of death was lower in the period 2011–2013 than in the period 2008–2010 (aOR 0.841, 95% CI 0.764–0.926). Adjustment variables (age, sex, Charlson score and type of resection) were significantly linked to IHM, whereas the type of hospital was not.

The French national strategy for quality improvement seems to have induced a significant decrease in IHM.

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Introduction

Currently, pulmonary resection remains the most efficient treatment for lung cancer [1]. However, despite improvements in the quality of care for lung cancer, pulmonary resection is still associated with postoperative mortality ranging from 2.5% to 3%, according to large databases [2, 3]. The quality of care depends on structure, process and outcomes [4, 5]. Structure relates to the organisation of care, such as the number of beds in hospitals or the number of nurses; process relates to actual actions of care, such as whether the patient receives medication or surgery within a certain timeframe; and outcomes include patient outcome measures such as in-hospital mortality (IHM). Differences in IHM between centres could be explained not only by the quality of care, but also by patient characteristics, registration bias and residual confounding [5, 6].

In 2009, a national strategy for quality improvement in cancer management (the "Plan Cancer"), which included new measures, was implemented to improve cancer care and was imposed in French hospitals [7]. These measures concerned cancer research, screening and the medical and surgical management of lung cancer patients. To obtain authorisation, the surgical team has to achieve >30 lung resections per year [8].

Few studies have used national databases to analyse the evolution of practices for lung cancer surgery over a defined period [2, 9–14], and few studies based on reports from institutions or the literature have been published [15–19]. It remains difficult to interpret the results of these studies because of the lack of data uniformity and the heterogeneity between single and/or specialised centres participating in these studies. This is why a national administrative database is an important tool to assess the quality of care, as it takes into account the characteristics of patients and all centres in the country. The French national administrative database for hospital care (Programme de Médicalisation des Systèmes d'Information (PMSI)) provides a huge amount of epidemiological information concerning hospitalised French patients [20–22]. Data pertaining to pulmonary resection for lung cancer are reliable enough to count such patients.

This nationwide survey was set up to monitor the performance of institutions using a framework of structure and outcome indicators, such as IHM. 5 years after the implementation of the national strategy for quality improvement Plan Cancer, we were interested to know the impact of this new organisation and the establishment of the threshold for hospital volume of activity for lung cancer surgery.

The objective of the present study was to estimate the period effect and to assess the influence of hospital volume on IHM within a large national cohort of patients operated on for lung cancer.

Materials and methods

Data source and study population

All data for patients who underwent pulmonary resection for lung cancer in France were collected from January 2005 to December 2013 from the national administrative database. This database was inspired by the US Medicare system. The reliability and validity of PMSI data have already been assessed [23]. Routinely collected medical information includes the principal diagnosis, secondary diagnoses and procedures performed. Diagnoses identified during the hospital stay are coded according to the International Classification of Diseases, 10th revision (ICD-10) [24]. We selected patients in whom a diagnosis of primary lung cancer was coded as the principal discharge diagnosis (all codes C34). Procedures are coded according to the common classification of medical procedures (Classification Commune des Actes Médicaux). For all patients, lung cancer was proven by pathology analyses according to the 2004 World Health Organization classification of lung cancer [25]. Surgery-related variables included the surgical approach (thoracotomy or video-assisted thoracic surgery), the type of resection (limited resection, lobectomy, bilobectomy and pneumonectomy), bronchoplasty and the extent of the pulmonary resection (to the chest wall, the left atrium, the carina, the diaphragm and the superior vena cava).

Patient characteristics

Baseline demographics included age and sex. From the national administrative database, we included the following comorbidities: pulmonary disease (chronic bronchitis of emphysema), heart disease (coronary artery disease, cardiac arrhythmia, congestive heart failure, valvular heart disease, pulmonary artery hypertension or pulmonary embolism), peripheral vascular disease, alcoholism, liver disease, cerebrovascular events, neurological diseases (hemiplegia or paraplegia), dementia, diabetes mellitus without complications, diabetes mellitus with complications, renal disease, coagulopathy, leukaemia, lymphoma, ulcer disease, history of malignant disease, obesity, other therapies (preoperative chemotherapy or steroids) and HIV/AIDS. We also calculated a modified Charlson comorbidity index (CCI) as a marker of comorbidity [26].

Hospital characteristics

In France, establishments that perform thoracic procedures are classified as nonuniversity public hospitals, private hospitals and university hospitals. The explanatory variables of interest were hospital volume of

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pulmonary resections for lung cancer. For each hospital, the number of times each type of pulmonary resection was performed was calculated in the period from January 1, 2005 to December 31, 2013. Hospital volume was defined as the mean number of procedures performed per year, and was classified into three evenly sized groups (low: <13; medium: 13–43; and high: >43), following the calculation of quintiles and taking into account the literature.

We defined three periods: 2005–2007 (before Plan Cancer), 2008–2010 (implementation of new measures of Plan Cancer) and 2011–2013 (after Plan Cancer). The period could thus have had an impact on the quality of care [7].

Outcome measurements

IHM was defined as any patient who died in hospital (including transferred patients) within the first 30 days after the operation and those who died later during the same hospitalisation.

Statistical analyses

Descriptive data were expressed as n (%) for qualitative variables and as mean±SD for continuous variables. Means were compared using a parametric test (ANOVA). We used a logistic regression model to construct prediction models for poor outcomes [27]. All models were constructed using backward stepwise variable selection. Step-down variable selection using Akaike's information criterion was used as a stopping rule [27]. Interaction effects were sought for all variables included in the model. The discriminative ability of the model was expressed by the area under the receiver operating characteristic curve (AUC) [28]. The reliability of the model was assessed using the Hosmer–Lemeshow goodness-of-fit test [29].

Uncertainty was estimated using a fixed-effect logistic regression model with an offset predictor model and centre as a categorical variable [26]. The standard error of the estimated coefficient, representing the mean outcome (σ2), indicated the uncertainty within the hospital [28].

We fitted a random-effect logistic regression model (multilevel model) to estimate unexplained heterogeneity, indicated by τ2 or the between-centre variance [28]. The variance indicates beyond-chance differences between hospitals.

To estimate rankability, we used the following formula: $\rho=\tau^2/(\tau^2+\text{median } \sigma^2)$ [28]. Rankability can be interpreted as the part of heterogeneity between hospitals that is due to unexplained differences, and the rest is due to natural variation or chance [28]. All analyses were performed using SAS software (version 9.2; SAS Inc., Cary, NC, USA). Chi-squared tests were performed for qualitative variables.

Results

Patient characteristics

From January 2005 to December 2013, 76 235 patients were operated on for lung cancer in France. Patient characteristics are reported in table 1. In the IHM group, there was a significantly greater proportion of males, of older patients and patients with a past history of liver and kidney disease, neurological disease, metabolic disease and haematological disease. Moreover, there were significantly more patients with a history of malignancies or HIV/AIDS in the IHM group (table 1).

Management

IHM was 3% for limited resection, 3% for lobectomy, 5% for bilobectomy and 8.2% for pneumonectomy (table 1). The mortality rate for extended resection and sleeve resection was 6% and 5.5%, respectively (table 1). Most resections (92.1%) were performed by thoracotomy.

Hospital characteristics

Global crude IHM was 3.9% and decreased over the three periods from 4.3% to 3.5% ($p<0.01$), and the number of centres performing lung cancer surgery decreased from 296 to 209 centres ($p<0.01$) (table 2). There were 2975 (3.9%) deaths during the hospital stay or within 30 days. The IHM rate was significantly higher for nonteaching hospital (4.7%) than for teaching hospital (3.9%) and private centres (3.7%) (table 2).

Most of the patients (75%) were operated on in centres performing >43 procedures per year. ∼60% of the centres (n=206) had a mean <13 pulmonary resections per year, but these centres performed only 5.5% (n=4151) of the total number of procedures over the three periods (table 2). IHM was significantly higher in low-volume centres (<13 procedures per year) than in medium-volume centres (13–43 procedures per year) and high-volume centres (>43 procedures per year) at 5.25%, 4% and 3.75%, respectively ($p<0.01$) (table 2). The mean number of procedures per hospital increased over the three periods, but very high disparity remained between volumes in the different centres (figure 1).

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TABLE 1 Baseline characteristics associated with patient survival and in-hospital mortality

	Total population	Survivors	In-hospital mortality	p-value
Subjects	76 235	73 260	2975	
Demographics				
Sex				
Male	55 204	52 617 (95.3)	2587 (4.7)	<0.001
Female	21 031	20 643 (98.2)	388 (1.8)	
Age years		62.9±10.4	67.9±9.5	<0.001
History				
Pulmonary disease	25 863	23 828 (92.2)	2035 (7.8)	<0.01
Heart disease	13 506	12 340 (91.4)	1166 (8.6)	<0.01
Peripheral vascular disease	7891	7229 (91.4)	662 (8.4)	<0.01
Liver disease	727	557 (76.6)	170 (23.4)	<0.01
Neurological disease	3495	3151 (90.2)	344 (9.8)	<0.01
Metabolic disease	6770	6318 (93.3)	452 (6.7)	<0.01
Renal disease	1520	1332 (97.6)	188 (12.4)	<0.01
Hematological disease	2225	2020 (90.8)	205 (9.2)	<0.01
History of malignant disease	29 513	28 112 (95.2)	1401 (4.7)	<0.01
HIV/AIDS	896	696 (77.7)	200 (22.3)	<0.01
Other treatment	11 148	10 467 (94)	681 (6)	<0.01
Modified CCI score				
0	25 994	25 456 (98)	538 (2)	<0.001
1	10 354	9999 (96.6)	355 (3.4)	
2	9439	9062 (96)	377 (4)	
⩾3	30 441	28 736 (94.4)	1705 (5.6)	
Surgical management				
Type of pulmonary resection				
Limited resection	10 144	9830 (97)	314 (3)	<0.001
Lobectomy	52 254	50 620 (97)	1634 (3)	
Bilobectomy	3803	3596 (95)	207 (5)	
Pneumonectomy	10 034	9214 (91.8)	820 (8.2)	
Surgical approach				
Thoracotomy	70 256	67 425 (96)	2831 (4)	<0.01
Extended resection	12 390	11 653 (94)	737 (6)	<0.01
Sleeve lobectomy	2317	2189 (94.5)	128 (5.5)	<0.01

Data are presented as n, n (%) or mean±SD, unless otherwise stated. CCI: Charlson comorbidity index.

The variation in clinical characteristics and prognostic factors by hospital are reported in table 3. The percentage of major resections, such as bilobectomy and pneumonectomy, varied substantially between hospitals (0–6% and 0–16%, respectively) (table 3). Postoperative mortality varied substantially between hospitals (0–5%) (table 3).

TABLE 2 Hospital characteristics and in-hospital mortality

	Centres	Survivors	In-hospital mortality	p-value
Subjects n		73 260	2975	
Hospital volume procedures per year				
<13	206 (59.7)	3933 (5.4)	218 (5.25)	<0.01
13–43	68 (19.7)	14 258 (19.4)	610 (4)	
>43	71 (20.6)	55 069 (75.2)	2147 (3.75)	
Hospital type				
Nonteaching	83 (24)	6688 (9.1)	331 (4.7)	<0.01
Private	232 (67.2)	35 651 (48.7)	1388 (3.7)	
Teaching	30 (8.7)	30 921 (42.2)	1256 (3.9)	
Period				
2005–2007	296	21 013 (28.7)	942 (4.3)	<0.01
2008–2010	259	24 844 (33.9)	1041 (4)	
2011–2013	209	27 403 (37.4)	992 (3.5)	

Data are presented as n, n (%) or mean±SD, unless otherwise stated. Total population n=76 235.

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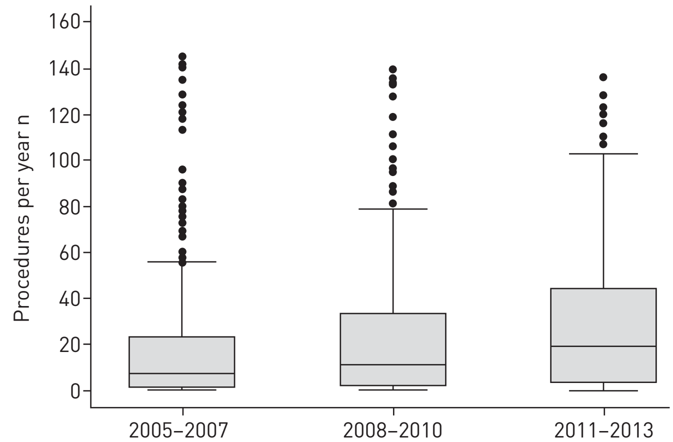

FIGURE 1 Distribution of number of procedures per year over the three periods: 2005–2007 (before Plan Cancer), 2008–2010 (implementation of new measures of Plan Cancer) and 2011–2013 (after Plan Cancer).

Prognostic factors

The results were the same in the fixed and random logistic models. The strongest predictors of poor outcomes were age, male sex, type of pulmonary resection, modified CCI score and comorbidities. The AUC of the model was 0.794. The Hosmer–Lemeshow goodness-of-fit was nonsignificant for this model (Chi-squared 15.3, degrees of freedom 10; p=0.06).

In the random logistic model, IHM was significantly linked to the volume of pulmonary resection: the adjusted (a)OR (95% CI) was 1.5 (1.2–1.8) for <13 procedures per year, 1.1 (0.94–1.3) for 13–43 procedures per year and 1 for >43 procedures per year (table 4). IHM was also significantly linked to the period of pulmonary resection: aOR (95% CI) 1.08 (0.98–1.2) for the period 2005–2007, 1 for the period 2008–2010 and 0.84 (0.76–0.93) for the period 2011–2013 (table 4). IHM was not linked to the type of hospital (table 4).

The rankability was 63%. This means that of the total variation between hospitals, 63% was not due to chance.

Discussion

In 2009, a new national strategy for quality improvement was implemented in French hospitals in order to improve the quality of the management of lung cancer patients. These measures concerned research, screening and the management of lung cancer patients. They also included for the first time the notion of volume of activity, to study its impact on markers of quality of care, such as IHM. This was based on numerous studies that have demonstrated a relationship between the number of surgical operations performed and the surgical outcomes for several surgical procedures including lung cancer resection [9, 10, 16, 18, 30–32].

Patient characteristics and surgical management

As previously described by many authors, our study highlighted that age, male sex and a high CCI score are prognostic factors of poor outcomes after lung cancer resection [13, 14, 33]. Moreover, IHM was significantly higher in bilobectomy and pneumonectomy because of the gravity of the resection itself [3].

Hospital volume of activity

We clearly demonstrated that IHM was higher in low-volume hospitals, where patients have a 1.5 higher risk of death during the postoperative period than patients undergoing surgery in high-volume centres,

TABLE 3 Variation in clinical characteristics and postoperative mortality by hospital ranked by the number of procedures performed per year

Male	75 (67.8–84)
Modified CCI score ⩾3	33 (17–49)
Lobectomy	66.5 (56–74)
Bilobectomy	3.4 (0–6)
Pneumonectomy	10 (0–16)
In-hospital mortality	2.9 (0–5)

Data are presented as median (interquartile range). CCI: Charlson comorbidity index.

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TABLE 4 Random-effects logistic regression model

Demographics	
Age	1.05 (1.05–1.06)
Sex	
Female	1
Male	1.8 (1.6–2)
Modified CCI score 0	1
1	0.88 (0.76–1.02)
2	1.04 (0.9–1.2)
⩾3	1.2 (1.04–1.36)
Past history	
Pulmonary disease	4 (3.7–4.4)
Neurological disease	2 (1.8–2.3)
Liver disease	7 (5.7–8.5)
Kidney disease	2 (1.75–2.5)
Metabolic disease	0.86 (0.76–0.97)
Haematological disease	1.84 (1.56–2.2)
Other treatment	1.18 (1.07–1.3)
Type of pulmonary resection	
Limited resection	1
Lobectomy	1.05 (0.92–1.2)
Bilobectomy	1.77 (1.46–2.14)
Pneumonectomy	3 (2.62–3.5)
Centre characteristics	
Hospital volume procedures per year	
<13	1.5 (1.2–1.8)
13–43	1.1 (0.94–1.3)
>43	1
Hospital type	
Nonteaching	1
Private	0.94 (0.76–1.5)
Teaching	0.94 (0.7–1.2)
Period	
2005–2007	1.08 (0.98–1.2)
2008–2010	1
2011–2013	0.84 (0.76–0.93)

Data are presented as odds ratio (95% confidence interval).

after adjustment for patient characteristics (including CCI score), the type of pulmonary resection, the period and hospital type. In 2012, von Meyenfeldt *et al.* [34] published a meta-analysis of 11 studies and highlighted significantly lower IHM in high-volume centres (OR 0.71, 95% CI 0.62–0.81). In a few studies, the number of lung cancer resections was not significantly linked to IHM [10, 11, 17, 19]. This could be explained by small numbers of patients recorded in databases that are not representative of all lung cancer resections performed in a country, and by the thresholds used to define low- and high-volume centres. Indeed, in all the studies dealing with hospital volume for lung cancer surgery, the thresholds used to define low volume were quite heterogeneous. In our study, the threshold was <13 procedures a year, which is a very low level of activity to perform major lung cancer resections such as pneumonectomy and lobectomy. In most previous studies, low volume was defined as 9–34 pulmonary resections a year, but the threshold remains very difficult to establish for lung cancer surgery [9, 10, 16, 18, 19]. Moreover, a too-small number of patients could be insufficient to highlight a relationship between major surgery and IHM. In 2014, Reames *et al.* [35] reported IHM in 3 282 127 patients who underwent one of eight gastrointestinal, cardiac or vascular procedures, and brought to light a relationship between IHM and volume of activity in the different centres for all of the procedures studied.

In our study, almost 60% of the centres had low activity, but managed only 5.5% of the patients. When comparing the three periods of the study, we found that there was a decrease in the number of low-volume centres, thus highlighting the effect of the cancer plan. This trend has also been seen in Canada. Indeed, Finley *et al.* [19] studied IHM after lobectomy for lung cancer using data from the Canadian Institute for Health Information Discharge Database, and highlighted a similar trend. This trend could be explained on the one hand by the decrease in the use of major resection such as bilobectomy and pneumonectomy as described previously [2, 3], and by the improvement in the quality of care in cancer centres and potentially by the regionalisation of lung cancer surgery in Canada on the other hand [19, 36].

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In France, through the Plan Cancer, the French health institute defined the minimum volume for lung cancer surgery at 30 resections per year. In this study, we can see that there are still centres performing lung cancer surgery even though they have insufficient volumes of activity, which results in higher IHM.

The notion that IHM can be decreased by performing major cancer surgery in high-volume centres was reported 20 years ago and underlies the regionalisation policy of the French health institute, whose main objective is to improve the quality of care in major cancer resection [37]. However, FINLEY *et al.* reported no decrease in IHM when volume was increased within a given hospital, but a decrease in IHM in all centres of Ontario after the establishment of the regionalisation of lung cancer surgery in this province of Canada in 2004 [19].

The use of rankability was introduced by VAN HOUWELINGEN *et al.* [28], for postoperative mortality in colorectal surgery. Rankability indicates which part of variation between hospitals is due to true differences and which part is due to chance [28]. The problem with ranking on crude hospital performance occurs when a rare event, such as IHM, is chosen [38]. Moreover, when some hospitals have small sample sizes, it makes the performance statistics unstable and the rank order unlikely to replicate [38]. In our study, rankability was 63%, suggesting a huge difference in quality of care between hospitals and implying that 37% of the variation in IHM between hospitals was due to chance. At present in France, despite the Plan Cancer, there are still too many centres performing lung cancer resections even though they have low volumes of activity. We should logically consider reducing the number of centres managing lung cancer surgery in order to improve the quality of care, while respecting the needs of the French population.

Hospital type

We also found significantly higher IHM in nonteaching centres than in teaching hospitals and private centres (4.7%, 3.9% and 3.7%, respectively), but the type of hospital was no longer a significant prognostic factor for IHM after adjustment for the other factors (table 4). ROMANO and MARK [16] studied the influence of the level of teaching on IHM for lung cancer surgery, and found no difference between high-volume, low-volume and nonteaching centres. However, more recently, BHAMIDIPATI *et al.* [12] studied outcomes after lung resection for 498 099 patients according to the type of hospital in the United States. They found that mortality in thoracic residency hospitals was significantly lower than that in general surgery residency hospitals, thus suggesting that specialist thoracic residency was an independent prognostic indicator [12]. In our study, this tendency was not observed. Nevertheless, in French teaching hospitals, only certified thoracic surgeons perform lung cancer resection, which is not the case in nonteaching or private hospitals where the proportion of certified thoracic surgeons is lower, and more general thoracic surgeons practice lung cancer resection.

Limitations

There are limitations to our study. Given the reliance on ICD-10 codes for the selection of patients and the ascertainment of outcomes, there was a potential for misclassification- or underdetection-related bias, especially for comorbidities. Coding practices vary significantly among institutions. Nevertheless, coding quality is checked by medical information professionals in each hospital to correct diagnoses and increase the level of recorded comorbidity. No details were available concerning the accommodation facilities of the centre (number of beds in surgical departments and intensive care units, number of days spent in intensive care, number of nurses and medical practitioners), the organisation (tumour board meeting, application of recommendations, qualification of the surgeons and surgery performed by residents) and details about the management (type of thoracotomy and chemotherapy).

However, the demographic characteristics, risk factors and outcomes of the present study population were very similar to those in previous French studies from the Epithor database [3].

Unlike the Epithor database, the French Administrative Database does not record lung cancer information, such as the stage of the disease, preoperative forced expiratory volume or the American Society of Anesthesiologists score.

Despite these limitations, the strength of our results is related to the large size of our sample (73 265 patients), with national recruitment. Finally, the results of the present study may be specific to the French healthcare system and cannot be generalised *a priori* to other countries with different healthcare systems.

Conclusion

IHM is significantly linked to hospital volume for lung cancer surgery in France, but not to the type of hospital. A significant decrease in IHM was observed in the period following implementation of the French initiative for clinical quality improvement. This was probably linked to the decrease in the number of centres allowed to perform lung cancer surgery (authorisation delivered according to the volume of activity), the increase in the volume of activity for authorised centres and better preoperative selection of patients. However, many centres are still performing <13 pulmonary resections a year for lung cancer.

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