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Chest physiotherapy revisited: evaluation of its influence on the pulmonary morbidity after pulmonary resection☆

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Abstract

Objective: The study aimed to evaluate if perioperative chest physiotherapy modifies the risk of pulmonary morbidity after lobectomy for lung cancer. **Methods:** We have reviewed a prospectively recorded database of 784 lung cancer patients treated by scheduled lobectomy (361 operated after implementing a new physiotherapy program). No other changes were introduced in the patients' perioperative management during the study period. A propensity matching score was generated for all eligible patients and two logistic models were constructed and adjusted. The first one (model A) included age of the patient, forced expiratory volume in 1 s (percent) (FEV1%) and predicted postoperative forced expiratory volume in 1 s (percent) (ppoFEV1%); for the second model (model B); chest physiotherapy was added to the previous ones. Using each model, patients' individual probability of postoperative complication was calculated and maintained in the database as a new variable (risk A and risk B). Individual risks calculated by both models were plotted on a time series and presented in two different graphs. **Results:** Rates of pulmonary morbidity were 15.5% before the intensive physiotherapy program and 4.7% for patients included in the implemented program ($p = 0.000$). The propensity score identified 359 pairs of patients. Model A included age ($p = 0.012$), FEV1% ($p = 0.000$), and ppoFEV1% ($p = 0.031$) as prognostic variables. Model B included age ($p = 0.012$), FEV1% ($p = 0.000$), and physiotherapy ($p = 0.000$). On graphic representation, a great decrease of the estimated risk could be seen after the onset of the physiotherapy program. **Conclusions:** Implementing a program of perioperative intensive chest physiotherapy reduced the overall pulmonary morbidity after lobectomy for lung cancer.

Keywords: Pulmonary lobectomy; Chest physiotherapy; Postoperative morbidity

1. Introduction

In 2006, we communicated that implementing a program of intensive perioperative chest physiotherapy for lobectomy patients, besides incentive spirometry and standard nursing care, contributed to decrease postoperative atelectasis and to cost savings due to lower hospital stay [1]. In this previous article, no changes were reported either in 30-day mortality or in overall postoperative cardio-respiratory morbidity.

To date, only a single-blind randomized clinical trial has been published evaluating if chest physiotherapy decreases the rate of pulmonary complications after lung resection [2]. According to the authors, no significant difference in the number of pulmonary complications and length of stay in any of the two groups of the study (active physiotherapy vs control) were found, at least in patients without chronic obstructive pulmonary disease (COPD) or low forced expiratory volume in 1 s (FEV1).

In this report, we have hypothesized that the population treated by specifically trained physiotherapists had a lower postoperative pulmonary morbidity, and we have tried to demonstrate it studying a homogeneous population of lung cancer patients treated by lobectomy using a propensity score-matching method.

2. Methods

2.1. Studied population

We have reviewed a prospectively recorded database of 784 lung cancer patients treated by scheduled lobectomy. In 361 cases, surgery was performed before November 2002 when we implemented a program of intensive chest physiotherapy which was described in a previous article [1].

2.2. Perioperative management

With the exception of the chest physiotherapy, perioperative management was uniform for all cases along the study period (1994–2009) and it has been also described in

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detail previously [1]. Shortly, all cases were approached by a posterior muscle-sparing or a small axillary thoracotomy, at the surgeon's choice. All cases were operated on by or under supervision by a scrubbed, senior thoracic surgeon. Anesthesia procedures were indicated and performed or supervised by a senior cardio-thoracic anesthetist. Preoperative antibiotic regimen consisted of a unique dose of cefuroxime 1500 mg that could be repeated 6 h later if surgery continues. Extubation was performed in the operating room and, after a few hours in the recovery room, patients were transferred to the cardio-thoracic ward. For postoperative analgesia, an epidural catheter was inserted and bupivacaine and fentanyl were infused through it during the first 2 days; it was then withdrawn and followed by oral paracetamol and non-steroid anti-inflammatory drugs. No other system of patient-controlled analgesia was employed. Postoperative radiological policy consisted of three basic X-rays: the first within the first 6 h postoperative in the recovery room, the second on the second postoperative day and, normally, the third after chest tube removal on day 3 or when appropriate. No other X-rays were indicated unless a clinical change made it necessary. X-rays were interpreted blindly by a specialist in chest radiology, and final agreement with the surgeon in charge was necessary to take any therapeutic action.

Nursing care was also homogeneous in all cases. Before the introduction of the chest physiotherapy program, ward nurses were in charge to encourage patients for early deambulation and deep breathing using an incentive inspirometer [1]. In the chest physiotherapy group, a therapist [1] specialized in respiratory physiotherapy was responsible for the treatment, starting the day before surgery and continuing up to discharge.

2.3. Variables and outcomes

The outcome selected as dependent variable was the postoperative occurrence of pulmonary complications. Any of the following postoperative events were considered: pulmonary atelectasis, pneumonia, or both. Positive diagnosis for any of these was provided if any of the postoperative chest radiographs reported consolidation or atelectasis, when leukocytosis (white blood cells (WBCs) over $11{,}000 \times 10^6\ l^{-1}$) and fever (corporal temperature $> 38\ ^\circ C$) is of pulmonary origin according to the attending surgeon, when a positive sputum culture is present or there is a change in the quality of the sputum respect to the preoperative sputum and, finally, if respiratory insufficiency ($SpO_2 < 90\%$ on room air) is present measured by a peripheral pulsioximetry. Starting in September 2008, the definition criteria of nosocomial pneumonia was updated according to the recently published Centers for Disease Control/National Healthcare Safety Network (CDC/NHSN) criteria [3].

The independent variables included in the analysis were: age of the patient, body mass index (BMI), preoperative FEV1%, and predicted postoperative FEV1% value (ppoFEV1%) calculated according the number of non-obstructed pulmonary segments to be resected at the operation, Charlson index, and clinical T status. Physiotherapy was also included among the independent variables as a binary one.

All studied variables and outcomes were defined and recorded prospectively on a customized computerized database. At the time of patient discharge, the first author of this article reviewed all the clinical records to upload into the database any postoperative event which could have been missed by the clinical staff. When starting this investigation, two authors manually reviewed the pulmonary complications of the series and agreed upon the nature of the complication and if pneumonia occurred before or after the atelectasis, whenever appropriate to fulfill the actual database.

2.4. Data analysis

2.4.1. Homogeneity of the series

After normality tests, patients' characteristics and preoperative continuous data (age, FEV1%, ppoFEV1%, BMI, and Charlson index) were compared using Student's *t*-test or by Wilcoxon rank-sum test as appropriate. Differences in clinical T status were evaluated by chi-square test on $n \times 2$ tables.

2.4.2. Propensity score-matched analysis

A propensity score was generated for all patients eligible and paired depending on whether they had undergone the implemented chest physiotherapy program or not. Intensive physiotherapy was the dependent variable and the covariates were age, FEV1%, ppoFEV1%, BMI, and Charlson index. Nearest-neighbor matching method was used without replacement. The preoperative values of the patients included in the two created groups attending the type of postoperative physiotherapy were compared by standardized differences. The patients were stratified by propensity score groupings to evaluate the occurrence of postoperative respiratory complications. All calculations were performed using Stata 10.0/PSMATCH2 (Leuven and Sianesi).

2.4.3. Logistic regression models and individual risk estimation

Using the propensity-matched population, two logistic models were constructed to evaluate the influence of having undergone a postoperative implemented chest physiotherapy program or not in the occurrence of postoperative pulmonary complications. Model A included all independent variables except for physiotherapy. Model B included the variables in model A plus the binary variable physiotherapy. To increase the robustness of the model, a resampling bootstrap technique (with 1000 replications) was used to calculate the standard error of the regression coefficients. Both models were recalculated introducing only variables with a 95% confidence interval (95%CI) coefficient not including the unit.

Using each model, a patient's individual probability of postoperative complication was calculated and archived in the database as a new variable (risk A and risk B).

2.4.4. Performance of the models and graphic representation of risk on time series

Individual risks calculated by both models were plotted on a time series and presented in two different graphs. To improve the clinical significance of the graphics, a local polynomial smoothing of the lines was performed.

All calculations and graphic were performed using Stata 10.0 (StataCorp, TX, USA).

3. Results

Before implementing the physiotherapy program, 361 cases were scheduled for lobectomy due to lung cancer. After the program, 423 cases were operated on.

Overall mortality was 2.2% (17 cases in the whole series, four in the physiotherapy group).

The propensity-matched score identifies 359 pairs of patients (cases and controls) that only differ in the type of postoperative physiotherapy. Clinical variables of both series of cases are presented in Tables 1 and 2. No differences were observed in continuous variables, and only the number of patients that received an induction chemotherapy differed within the categorical variables. In the series of patients with physiotherapy, more cT4 tumors and more patients with higher Charlson's index of co-morbidity were operated on although these differences do not present a statistically significant difference (cT4 $p = 0.19$; Charlson index $p = 0.22$).

Table 3 presents the frequency and the type of the recorded cardio-respiratory postoperative complications. We observed a 36.1% global postoperative morbidity in the whole group of patients: cardiac complications were 17.3% and pulmonary complications 9.7%. Rates of pulmonary morbidity were 15.5% before the intensive program and 4.7% once the program started ($p = 0.000$). The propensity matching score identifies 55 cases with a postoperative pulmonary complication before implementing the physiotherapy program and only 15 after implementation ($\chi^2 = 25.33$, $p = 0.000$).

Both regression models are presented in Table 4. Model A represents the risk for postoperative pulmonary complications when physiotherapy is not taken into account. It included age ($p = 0.006$), FEV1% ($p = 0.000$) and ppoFEV1% ($p = 0.022$). Model B represents the risk when physiotherapy is included. After recalculation, model B includes only age ($p = 0.012$), FEV1% ($p = 0.000$), and physiotherapy ($p = 0.000$).

In Fig. 1, the individual risk estimation calculated using model A was plotted on the date when surgery was performed. In the smoothed line, a transitory increase of

Table 1. Comparison of continuous variables in matched patients grouped by the type of perioperative management (before or after physiotherapy program).

	Median	Minimum	Max	*p*
Age				
Pre-P[a]	66	35	82	0.02
Physiot[b]	68	43	84	
Charlson index				
Pre-P	1	0	4	0.22
Physiot	1	0	6	
BMI				
Pre-P	25.56	15.2	38.9	0.06
Physiot	26.34	16.1	40.3	
FEV1%				
Pre-P	84.21	40	145	0.73
Physiot	83.78	42	143	
ppoFEV1%				
Pre-P	79	30	122	0.05
Physiot	79	39	112	

[a] Pre-P: cases operated on before implementing the physiotherapy program.
[b] Physiot: cases after implementation of the physiotherapy program.

Table 2. Comparison of categorical variables in matched patients grouped by the type of perioperative management (before or after physiotherapy program).

	Pre-P[a]	Physiot[b]	*p*
cT status			0.19
1	50	48	
2	246	237	
3	46	45	
4	8	19	
Induction chemotherapy			
No	333	316	0.03
Yes	26	43	

[a] Pre-P: cases operated on before implementing the physiotherapy program.
[b] Physiot: cases after implementation of the physiotherapy program.

Table 3. Frequency and type of the recorded morbidity of both series.

Type of complication	Pre-physiotherapy *n* (%)	Physiotherapy *n* (%)
Pneumonia	29 (21.3)	10 (7.3)
Respiratory insufficiency	13 (9.6)	7 (5.1)
Atelectasis	8 (5.9)	2 (1.5)
Atelectasis and pneumonia	19 (13.9)	8 (5.9)
Cardiac insufficiency	4 (2.9)	2 (1.5)
Atrial fibrilation	18 (13.2)	14 (10.3)
Coronary disease	2 (1.4)	0 (0)
Total	93	43

Table 4. Predictive models for pulmonary complications (matched cases).

	Coefficient	95% CI	*p*
Model A: before implementing the physiotherapy program*			
Age	0.246	0.005, 0.044	0.012
FEV1%	−0.028	−0.041, −0.014	0.000
ppoFEV1%	−0.021	−0.040, −0.002	0.031
Model B: after implementing the physiotherapy program**			
Age	0.017	0.003, 0.031	0.012
FEV1%	−0.035	−0.046, −0.023	0.000
Physiotherapy	−1.512	−2.151, −0.874	0.000

* Hosmer—Lemeshow goodness of fit test, $p = 0.384$.
** Hosmer—Lemeshow goodness of fit test, $p = 0.673$.

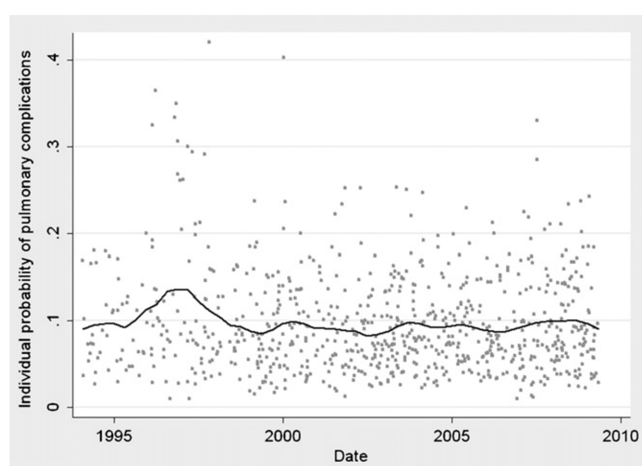

Fig. 1. Individual risk of complication calculated by regression model A. A temporary increase can be seen during the years 1996 and 1997, with slight variations along the rest of the period included in the study.

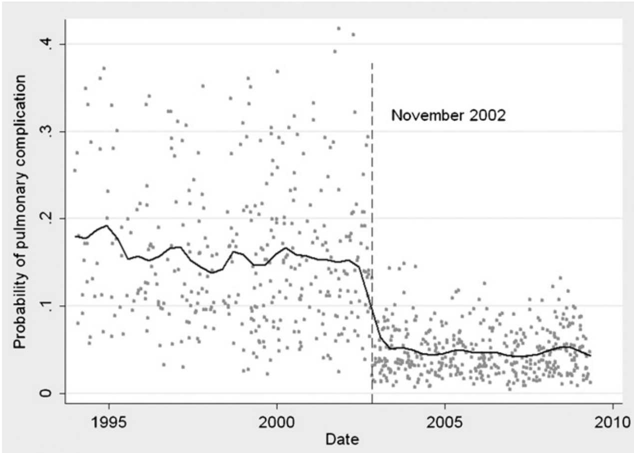

Fig. 2. Individual risk of complication calculated by regression model B. Vertical dotted line represents the onset of the physiotherapy program. A dramatic decrease of the probability can be seen afterwards.

the risk during 2 years is demonstrated. In Fig. 2, the individual risk calculated by model B is presented. The dotted vertical line represents the date when the physiotherapy program started (November 2002). A dramatic decrease of the estimated risk can be seen. Besides, the individual risk of the patients before and after that date have changed, being the risk superior to the one shown in Fig. 2 in patients operated before the physiotherapy program.

4. Discussion

In a previous investigation [1], we concluded that a perioperative intensive physiotherapy program added to standard nursing care and incentive spirometry reduces the rate of postoperative pulmonary atelectasis after lobectomy, with no additional costs. The case series in the current article is larger and more homogeneous, as lobectomy performed in cases of metastasis, chronic infections, or any other indication have been excluded and the propensity score methodology has converted the analysis in a quasi-experimental study. We have tried to demonstrate the effectiveness of chest physiotherapy to decrease the overall prevalence of pulmonary complications following pulmonary lobectomy.

Chest physiotherapy performed by specialized therapists constitutes a routine in most thoracic surgery units, and it has been recently recommended as it may produce functional benefits in resectable lung cancer patients [4]. Unfortunately, this recommendation was not evidence based. Recently, the preliminary results of the first single-blind randomized trial to assess this topic have been published [2]. The authors conclude that perioperative targeted respiratory physiotherapy may not be required in addition to standard nursing care involving a clinical pathway after major lung resection. In our opinion, the article deserves some comments [5]. The authors stopped the accrual of patients to the study due to the unexpectedly low number of pulmonary complications, attributable to the effectiveness of the standard nursing care which is better than the one we can offer in our own center with a nurse—patient rate of 1/12. In fact, nursing care of the control group [6] was probably above the standard in many centers.

We have not considered designing a randomized clinical trial on the subject due to our previous experience with atelectasis rate reduction. A good alternative to an experimental approach to demonstrate the effectiveness of physiotherapy in lung resection is to introduce the propensity-matched methodology [7] and to plot the results in an interrupted time-series analysis [8]. As it is well known, the propensity matching methodology is an approach to estimate causal treatment effects because it helps to avoid the always present selection bias by finding in a large group of control patients, individuals who are similar to the cases, one by one, in all relevant pre-treatment characteristics. In our study using this methodology, we create 359 pairs of case-control patients homogeneous and comparable. On the other hand, to increase the capability of discrimination, an interrupted time-series analysis has been added over the propensity score matching. In this type of studies, changes of the trend of a continuous variable are studied after an intervention. In our case, the selected continuous variable to be studied was pulmonary morbidity rate. Unfortunately, 719 patients is not a large population and it is possible that we do not have enough numbers to perform this kind of study, although, as it can be seen in Figs. 1 and 2, the new physiotherapy program clearly modified a relatively stable estimated risk in the absence of another event that could have influenced the outcomes. Both factors — previous changes in tendencies and unveiled simultaneous interventions — are reported as frequent bias in time-series analysis [8,9]; but they have been, to some extent, controlled by the propensity matching method. In the absence of a perfectly designed and performed interrupted time-series analysis, data shown in this article provide some scientifically supported evidence for the widespread belief among surgeons that specific perioperative respiratory therapy programs should be implemented.

Besides the absence of randomization, the main limitation of our study is that neither Diffusion Lung Capacity for Carbon Monoxide (DLCO) nor predicted postoperative Diffusion Lung Capacity for Carbon Monoxide (ppoDLCO) have been included in risk modeling. Although measuring lung diffusion capacity is currently paramount in preoperative risk evaluation of lung resection candidates [2], it was not so at the time of the start of the recruitment period for this investigation. Due to the lack of DLCO data in many cases at the beginning of our experience, we have not considered DLCO for risk modeling. The same limitation can be found in the development of the current European risk model for in-hospital mortality published in 2005 [10].

In this series, surgical approach was surgeon's choice. Then, it could be hypothesized that patients operated on through small axillary incision could have experienced less pain influencing the outcomes. The topic has been studied previously by Ochroch and co-workers [11] finding no differences in pain or pulmonary function between both types of incisions.

In conclusion, implementing a program of perioperative intensive chest physiotherapy reduced the overall pulmonary morbidity after lobectomy for lung cancer.

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Editorial comment

Back to the future: chest physiotherapy comes full circle

Keywords: Lung resection; Lung cancer; Chest physiotherapy; Postoperative complications

Selection of patients for lung resection is an art form that has gradually been modified over time, based on the identification of specific preoperative and operative risk factors. Patient-specific risk has often been considered fixed except perhaps in the population of patients with severe emphysema in whom intensive cardiopulmonary rehabilitation over a period of 4—6 weeks preoperatively is believed to possibly reduce risk. Thus, most patients (and their surgeons) have been faced with an unalterable risk of morbidity and mortality associated with major pulmonary surgery that must be balanced against its potential benefits.

Intuitively, providing expert intensive chest physiotherapy in the perioperative period should reduce the risk of pulmonary complications and resultant hospital length of stay and costs of care after major lung resection. Those of us who were trained by the first or second generation of thoracic surgeons are familiar with their mantra that vigorous chest physiotherapy is the primary means for reducing the incidence of postoperative pulmonary complications. Mr Ronald Belsey used to instruct the mothers of his pediatric patients on appropriate techniques, and could count on the motivation of these newly designated practitioners to do everything in their power to help their children.

However, the extolled benefits of postoperative chest physiotherapy have been difficult to demonstrate unequivocally, leading to a lack of general utilization in this increasingly evidence-based and cost-contained atmosphere in which we work. In addition, some institutions expect unspecialized physical therapists or nurses to provide these services when their time is already overcommitted to a host of other responsibilities.

The landmark report by Novoa and colleagues demonstrates conclusively the benefits of perioperative pulmonary physiotherapy, when performed by experts, for both patients and the institutions in which the patients are treated [1]. The substantial reduction in morbidity that they report as a result of instituting this routine therapy for their major lung resection patients should serve as a wakeup call to surgeons and institutions that do not provide such services for their patients. It is time to develop protocols for chest physiotherapy in postoperative patient management that resemble those of our forebears.

How to implement such services is not fully addressed by this report, and additional work will be necessary to determine in what manner such treatment should be included as a standard of care. Are there patients who are in sufficiently good condition that they would not benefit from these additional services? Are there patients who are considered high-risk candidates for surgery who were refused an operation but now who may be considered for surgery because of an anticipated reduction in surgical risk? What is the optimal daily frequency of treatment, and for how many days prior to and after surgery should such treatment be provided? Which individuals are best capable of providing such therapy?