Perioperative Lung Function Monitoring for Anatomic Lung Resections

Gregor J. Kocher, MD,* Konstantinos P. Gioutsos, MD,* Markus Ahler, MD, Manuela Funke-Chambour, MD, Sebastian R. Ott, MD, Patrick Dorn, MD, Jon Lutz, MD, and Ralph A. Schmid, MD

Division of General Thoracic Surgery, Department of Pulmonology, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

Background. The aim of this study was to prospectively investigate the correlation between postoperative spirometry values and pulmonary complications after anatomic lung resections. In addition, we compared postoperative pulmonary function changes between open and minimally invasive approaches.

Methods. Three hundred eighty-four patients who underwent an anatomic lung resection at our institution between June 2013 and June 2016 were enrolled in this prospective observational trial. Bedside spirometry was performed before surgery and postoperatively every second day until discharge. For the 250 patients who completed the trial, the following data were collected and analyzed: spirometry findings, pain management, surgical procedure, and postoperative complications. A propensity score matched analysis was performed to compare open and minimally invasive approaches.

Results. Postoperative pneumonia was significantly more frequent after open surgery (13.2% versus 4.4%, $p = 0.016$); furthermore, these patients showed significantly greater losses of forced expiratory volume in 1 second on postoperative day 4 compared with patients without pneumonia (loss in percent from preoperative absolute values: 43.2% versus 32,2%, $p = 0.013$). When focusing on patients without pneumonia, propensity matched analysis revealed a significantly faster recovery of forced expiratory volume in 1 second on postoperative day 4 in the minimally invasive group compared with the open group ($p = 0.011$).

Conclusions. Daily bedside spirometry might be a helpful diagnostic adjunct for early recognition, and hence, timely treatment, of pulmonary infection after open anatomic lung resections. In addition, minimally invasive techniques not only resulted in a lower rate of pulmonary infections but also resulted in faster postoperative recovery of pulmonary function and shorter hospital stay.

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Pulmonary complications, especially pneumonia, are common after thoracic surgery and often result in problematic courses associated with longer hospital stays and increased morbidity and mortality. For example, Schussler and colleagues [1] reported a pneumonia incidence of 25% after major lung resections, resulting in a significant increase in noninvasive ventilation, reintubation, and longer intensive care unit and hospital stays, as well as an increased mortality rate of as high as 19%. Therefore, not only prevention but also early recognition of pneumonia after lung surgery is of utmost importance to decrease morbidity and mortality rates.

Little is known about the perioperative lung function changes in patients undergoing major lung resections. So far there is only one study investigating the association between lung function and postoperative complications after pulmonary resection. No significant difference in spirometry data was found when comparing patients with postoperative complications (cardiac, respiratory, and surgical) and patients without complications. However, only a relatively small cohort of 60 high-risk patients were evaluated in this study [2]. Conversely, minimally invasive (MI) surgical techniques gained broader acceptance in recent years and a few small studies compared postoperative lung function values between open and MI approaches, indicating better lung function after video-assisted thoracic surgery (VATS) lobectomy in the first days as long as 3 months after surgery [3–5].

The aim of the present study was to investigate whether frequent spirometry follow-up could be a useful tool in the early recognition of postoperative pulmonary complications after anatomic lung resections. Therefore, the primary endpoint of this study was to investigate whether the postoperative loss in forced expiratory volume in 1 second (FEV_1) would be the same in case of a postoperative pulmonary infection compared with the postoperative course without complications (null hypothesis). Furthermore, as a secondary endpoint, the influence of the resection modality—open versus MI—on postoperative lung function recovery was investigated.

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*Drs Kocher and Gioutsos contributed equally to this work.

Address correspondence to Dr Kocher, Division of General Thoracic Surgery, University Hospital Bern, CH-3010 Bern, Switzerland; email: gregor.kocher@insel.ch.

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Patients and Methods

This is a monocentric prospective observational study including all patients undergoing an anatomic lung resection at our institution between June 2013 and June 2016. Minor patients (ie, age less than 18 years) and patients undergoing extended pulmonary resections including resection of the diaphragm, chest wall, or bronchoplastic procedures were excluded. The primary endpoint was the evaluation of the course of recovery of postoperative FEV_1 as an indicator of pulmonary postoperative complications.

The study was approved by the Local Ethics Committee, and informed consent was obtained from all patients. The research was conducted according to recommendations outlined in the Helsinki Declaration.

Surgical Technique, Extent of Resection

The modality of the approach (open or MI) and the type of resection (segment, lobe, or lung) were chosen by the surgical team preoperatively, and this decision was based exclusively on medical data and not influenced by the aims of this study. At our institution, a gradual transition from a mainly open approach toward a mainly MI technique took place, starting in June 2014. Therefore, two comparable groups of patients were created during the study period.

Open resection was performed through a muscle-sparing anterolateral thoracotomy in the fifth intercostal space. For the conventional thoracoscopic approach, used from the beginning of the study until November 2014, a standard three-port technique was applied [6]. In November 2014, the conventional three-port technique was replaced by a single-incision thoracoscopic approach, as described by Gonzalez-Rivas and associates [7]. In all procedures, the artery, vein, and bronchus were exposed and divided separately, and systematic lymphadenectomy was performed. On the first postoperative day (POD), chest physiotherapy and inhalations with a standard dose of ipratropium bromide (Atrovent; Boehringer Ingelheim GmbH, Ingelheim, Germany) and salbutamol (Ventolin; GlaxoSmithKline, Middlesex, UK) four times a day were started in all patients.

Concerning the extent of the resected lung volume, three groups were defined: (1) segmentectomy group (resection of one to three lung segments, including resection of the right upper lobe, middle lobe, and lingula-sparing left upper lobe); (2) lobectomy group (resection of four or five lung segments); and (3) pneumonectomy group.

Bedside Spirometry

Spirometry was performed preoperatively and on every second day after surgery, starting on POD 2, by an independent nurse using a portable spirometer (Micro I; CareFusion, Yorba Linda, CA). The measurement procedure was standardized and performed with the patient in a sitting position (best of three measurements) after the morning inhalation round.

The FEV_1 was chosen as the main variable to be measured because this task had to be a straightforward procedure that could be performed with the portable spirometer device and without the need for additional calculations (eg, percent of predicted values), which would have been more time consuming and an additional source for potential errors. Furthermore, the calculation of percent of predicted values always leads to some degree of distortion of the reality (ie, leading to underestimation or overestimation of values in many patients [8]); therefore, in the present study, a comparison of the postoperative decline in FEV_1, which was calculated as loss in percentage of absolute preoperative FEV_1 values, was chosen to allow optimal comparability of the different patient groups.

At the time of spirometry, pain scores were registered using the visual analog scale (VAS), as intense pain might influence the performance of spirometric measurement. The FEV_1 values were recorded on a separate study sheet not accessible to the treating physician on the ward (observer blinded). If the VAS pain score was 3 or greater at the time of any of the lung function tests, the test result was not recorded and the test was repeated in the afternoon after optimizing pain management. If no test results were available because the patient had a pain score of 3 or greater or was otherwise incompliant, the subject was excluded from the study.

Pain Management

Basic pain management consisted of a cumulative standard dose of 4 g paracetamol and 4 g metamizole per day for all patients. In addition, an epidural catheter was placed in most patients undergoing thoracotomy. In the MI group, an intercostal nerve block with a standard dose of 20 mL 0.75% ropivacaine was administered during surgery. If deemed necessary, an additional hydromorphone patient-controlled analgesia pump was installed after surgery.

Pulmonary Complications

The main postoperative pulmonary complications were pneumonia, acute exacerbation of chronic obstructive pulmonary disease (AECOPD), atelectasis, and prolonged air leak (ie, air leak duration more than 5 days). In alignment with Schussler and colleagues [1], pneumonia was defined if all of the three following criteria were fulfilled: (1) clinical signs of a pulmonary infection (ie, fever of 38°C or higher combined with productive cough or dyspnea or both); (2) a new rise of inflammatory markers (ie, white blood cell count 12×10^9 or greater and elevated C-reactive protein); and (3) new radiographic infiltrates on chest radiograph without another explanation. On diagnosis and microbiological sampling (eg, sputum, if productive), an empiric antibiotic treatment was started with amoxicillin/clavulanic acid, cefepime, or piperacillin/tazobactam, depending on the risk profile of the patient.

The diagnosis of AECOPD was made in case of an increase in sputum production in patients with known COPD and increased frequency or severity of coughing