Early reoperation performed for the management of complications in patients undergoing general thoracic surgical procedures

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ABSTRACT

Objective: To detect the rate and predisposing factors for the development of postoperative complications requiring re-operation for their control in the immediate postoperative period.

Methods: During the time period 2009-2012, 719 patients (male: 71.62%, mean age: 54±19 years) who underwent a wide range of general thoracic surgery procedures, were retrospectively collected. Data of patients who underwent early re-operation for the management of postoperative complications were assessed for identification of the responsible causative factors.

Results: Overall, 33/719 patients (4.6%) underwent early re-operation to control postoperative complications. Early re-operation was obviated by the need to control bleeding or to drain clotted hemothoraces in nine cases (27.3%), to manage a prolonged air leak in six cases (18.2%), to drain a post-thoracotomy empyema in five cases (15.2%), to revise the thoracotomy incision or an ischemic musculocutaneous flap in five cases (15.2%), to manage a bronchopleural fistula in four cases (12.1%), to manage persistent atelectasis of the remaining lung in two cases (6.1%), to cease a chyle leak in one case (3%) and to plicate the right hemidiaphragm in another one case (3%).

The factors responsible for the development of complications requiring reopening of the chest for their management were technical in 17 cases (51.5%), initial surgery for lung or pleural infections in 9 (27.3%), the recent antiplatelet drug administration in 4 (12.1%) and advanced lung emphysema in 3 (9.1%). Mortality of re-operations was 6.1% (2/33) and it was associated with the need to proceed with completion pneumonectomy in the two cases with persistent atelectasis of the remaining lung and permanent parenchymal damage.

The majority of complications requiring reoperation were observed after lung parenchyma resection (17 out of the 228 procedures/7.4%) or pleurectomy (7 out of the 106 procedures/6.5%). Reoperations after video-assisted thoracic surgery (VATS) were uncommon (2 out of the 99 procedures/2%).

Conclusions: The rate of complications requiring reoperation after general thoracic surgery procedures is low and it is mainly related to technical issues from the initial surgery, the recent administration of antiplatelet drugs, the presence of advanced emphysema and surgery for infectious diseases. The need to proceed with completion pneumonectomy has serious risk for fatal outcome.

KEYWORDS General thoracic surgery; postoperative complications; post-thoracotomy complications; rethoracotomy; reoperation; early reoperation

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Introduction

General thoracic surgery is associated with the development of a wide range of postoperative complications. The commonest observed postoperative complications are atelectasis, supraventricular arrhythmias, prolonged air leak and bleeding. Postoperative retention pneumonia, empyema, bronchopleural fistula formation, chyle leak, wound problems, lobar torsion

and nerve injuries are observed less frequently (1,2). In addition, other specific complications are related with specific procedures (i.e., pneumonectomy, resection of Pancoast tumors, esophagectomy). Most of the postoperative complications in general thoracic surgery are managed conservatively or with minor interventions, such as fiberoptic bronchoscopy, reinsertion of chest tube drain, chest needle drainage or the application of a vacuum assisted closure (VAC) device (1,2).

The need to proceed with reoperation in the immediate postoperative period in order to resolve a postoperative complication is not common and the observed rate after general thoracic surgery procedures or isolated lung parenchyma resection is reported to vary between 1.2% and 3.7% (3-7). Interestingly, most of such series in Medline (where an abstract is at least available to read) are published in German, Russian or Italian language (3,4,6-10), while only one series even though coming from Germany is published in English (5). These series are mostly historical and include patients who underwent thoracic surgery from 1963 until recently. The current study evaluates early reoperations which are performed after general thoracic surgical procedures in order to resolve a postoperative complication, focusing mainly in the observed rate and the predisposing factors for the development of such complications in almost the whole spectrum of the procedures performed in the era of modern general thoracic surgery.

Patients and methods

During the time period 2009-2012 (four years), 719 patients (mean age: 54±19 years, male: 71.62%) underwent a variety of general thoracic surgery procedures under general endotracheal anesthesia in an Academic/teaching Cardiothoracic department. Minor procedures, such as diagnostic/interventional fiberoptic or rigid bronchoscopy, thoracoscopy under local anesthesia, chest tube insertion, pericardiocentesis, insertion of a tracheal "T" tube, biopsies of scalene lymph nodes, open and dilational tracheostomy were excluded from the study.

All patients who underwent early reoperation for the management of surgical postoperative complications were retrospectively collected from the electronic database of the department. Early reoperation was defined as any reoperation performed to control a postoperative complication within the four weeks immediate postoperative period or within the initial postoperative hospitalization if this exceeding more to four weeks. Reoperations that were performed electively during the 4-week immediate postoperative period for oncologic reasons (completeness of resection) were excluded from the analysis. The notes of hospitalization and the notes of surgical procedures were assessed to retrieve all the required information for identifying the predisposing factors for reoperation.

A cumulative list of the procedures that were performed during the study period is presented in Table 1. Staging mediastinoscopies, anterior mediastinotomies and thoracoscopies that were performed at the same time with thoracotomy were not recorded as isolated procedures. The surgical access used to accomplish the above mentioned procedures were: thoracotomy in 405 cases (56.3%), video-assisted thoracoscopy in 99 cases (13.7%), cervical incision (including the 47 video-mediastinoscopies) in 63 (8.7%), median full or upper sternotomy in 51 (7.1%), anterior mediastinotomy in 24 (24%), axillary minithoracotomy in 21 (2.9%), suxiphoid incision in 12 (1.6%) and other incisions used for the resection of chest wall tumors and the correction of chest wall deformities (which do not fall within the typical thoracic approaches) in 44 cases (6.1%). Statistical analysis was performed with the IBM SPSS Statistics v 10.0.

Results

Overall, 33 out of the 719 patients (4.6%) underwent early re-operation for managing surgical postoperative complications during the 4-year study period. A list of all the postoperative complications observed during the study period is presented in Table 2. The overall incidence of complications observed in the 719 patients was 22.2%.

Reoperation for bleeding and/or clotted hemothorax

Nine patients underwent reoperation to stop bleeding and/or to remove the accumulated blood clots from the chest. The initial access was a thoracotomy incision in all the nine cases. None from a total of the 99 performed video-assisted thoracic surgery (VATS) procedures (not including VATS lobectomies and thymectomies) was complicated with postoperative bleeding. Reopening of the thoracotomy incision took place between the day of surgery and the 5th postoperative day (median: 1.0 day). Details on initial procedures that were complicated with postoperative bleeding, day of reoperation, active bleeding detection and predisposing factors for bleeding are presented in Table 3. The effect of reoperation on overall postoperative hospital stay was moderate, since the median hospital stay from reoperation to discharge was eight days.

The majority of reoperations were performed on the 1st postoperative day. It is notable that four patients were receiving antiplatelet drugs before surgery (clopidogrel or the combination of aspirin and clopidogrel) for cardiovascular diseases which were discontinued 5 to 7 days before surgery in the three elective

Table 1. Cumulative list of all general thoracic surgical procedures performed during the study period. The 33 reoperations that were performed for the management of complications are not included in the table below.

Procedure per organ	Open procedures	Video-assisted procedures
Lung and pleural surgery		
Lobectomy/bilobectomy	140	–
Pneumonectomy	35	–
Anatomical segmentectomy	5	–
Wedge resection and metastasectomies	48	5
Enucleation/resection of pulmonary hamartoma	7	1
Enucleation of lung hydatid cyst	7	–
Drainage of benign persistent lung abscess	3	–
Exploratory thoracotomy or thoracoscopy, lung and lung tumor biopsies	34	20
Bullectomy and pleurectomy or isolated pleurectomy	61	44
Drainage of empyema and lung decortication	31	3
Pleuectomy/decortication for mesothelioma	3	–
Drainage of post-traumatic clotted hemothorax	7	2
Pleural biopsy/talc pleurodesis	–	18
Mediastinal surgery		
Biopsy of mediastinal tumors and mediastinal lymph nodes	28 (anterior mediastinotomy: 24 & thoracotomy: 4)	52 (video mediastinoscopy: 47 & VATS: 5)
Resection of mediastinal tumors	48	–
Extented transternal thymectomy for myasthenia Gravis	17	–
Removal of mediastinal cysts	7	–
Creation of pericardial window through the subxiphoid route or left anterior thoracotomy*	15	–
Various accesses to the spine for neurosurgical procedures	7	–
Chest wall surgery		
Resection of chest wall tumor and chest wall reconstruction	22	–
Resection of chest wall tumor without chest wall reconstruction	13	–
Repair on anterior chest wall deformities	7	1
Repair of sternal fracture	2	–
Tracheal and esophageal surgery		
Repair of tracheoesophageal fistula	6	–
Resection of tracheal stenosis	6	–
Resection of Zenker's diverticulum	2	–
Iwor-Lewis esophagectomy	3	–
Removal of esophageal foreign body	2	–
Diaphragmatic surgery		
Repair of hemidiaphragm (hernia, traumatic rupture, defect)	5	–
Plication of hemidiaphragm for eventration	2	–
Total	573	146

*, not recorded as cardiac surgery procedures in the database of the department.

Table 2. Cumulative list and rate of the observed complications not requiring and requiring redo thoracic surgery for their management in the 719 patients of the study.

	No. of patients (%)
Complications not requiring intervention or requiring minor intervention	
Postoperatively established supraventricular tachyarrhythmias*	41 (5.7)
Prolonged air leak (>5 days)	27 (3.7)
Wound problems not requiring revision	19 (2.6)
Atelectasis requiring bronchoscopy	18 (2.5)
Pleural effusion requiring needle or chest tube drainage	12 (1.6)
Hygroma of the chest wall requiring needle drainage	4 (0.5)
Permanent recurrent laryngeal nerve palsy [3] or Horner's syndrome [1]	4 (0.5)
Acute renal failure requiring hemofiltration	1 (0.1)
Brain embolization	1 (0.1)
Total	127 (17.6)
Complications requiring reoperation	
Bleeding/clotted hemothorax	9 (1.2)
Prolonged air leak (>5 days)	6 (0.8)
Deep thoracotomy wound infection and dehiscence or ischemia of musculocutaneous flap requiring revision	5 (0.7)
Postoperative empyema thoracis without bronchopleural fistula	5 (0.7)
Bronchopleural fistula	4 (0.5)
Persistent atelectasis of the remaining lung after lobectomy	2 (0.3)
Permanent phrenic nerve damage—hemidiaphragm paralysis	1 (0.1)
Chyle leak	1 (0.1)
Total	33 (4.6)

*, preexisting supraventricular arrhythmias (i.e., chronic atrial fibrillation) are not included.

procedures. One patient, under treatment with aspirin and warfarin for coronary artery disease and chronic atrial fibrillation, who was initially operated for traumatic lung laceration, bled the 5th postoperative day since the re-administration of aspirin and warfarin.

Reoperation for the control of prolonged air leak

Six patients underwent reoperation to control a persistent prolonged air leak. Table 4 presents the initial procedures, the predisposing factors for the prolonged air leak which did not respond to conservative treatment, the site of air leak detected during reoperation and the accesses used during reoperation. Regarding the operative technique used in the initial procedures, stapling lines were not reinforced with synthetic materials during the study period. One-way intrabronchial valves were not used in the attempt to control the prolonged air leak. Reoperations were performed between the 9th and 29th postoperative day (median: 10.5 days) resulting in air leak cessation and full lung expansion in all cases. The time from reoperation to discharge from the hospital varied between 3 and 14 days (median: 5.5 days) (Table 4).

The decision to reoperate was always made after failure of the conservative treatment manoeuvres, such as repeated blood pleurodesis or position of a chest tube drain in the 2nd intercostal space in the midclavicular line after the three upper lobectomies. The criteria to reoperate were: (I) failure of the lung or remaining lung to fully expand after discontinuation of the applied to the chest tube(s)/suction (–20 cm H_2O) and (II) a trend obtained by the Thopaz digital drainage system (Medela AG, Switzerland) with no tendency of the leak to diminish during several days, even in the lung was fully expanded in plain chest radiography.

Reoperation to drain a post-thoracotomy empyema (without fistula)

Reoperation for the drainage of empyema was made after thoracotomy in four cases and after a VATS procedure in the last case. Details of the initial procedures and subsequent

Table 3. Details on reoperations for postoperative bleeding.

Gender, age (years)	Initial operation/access	Day of reoperation	Active bleeding	Reoperation	Predisposing factor	Day of discharge after reoperation
Male, 62	Bullectomy and pleurectomy/ anterolateral thoracotomy	1st	No	Redo thoracotomy*	Antiplatelets	10th
Female, 69	Bullectomy and pleurectomy/ anterolateral thoracotomy	1st	No	Redo thoracotomy*	Technical (failure to achieve proper hemostasis)	7th
Male, 41	Bullectomy and pleurectomy/ anterolateral thoracotomy	4th	No	Redo thoracotomy*	Antiplatelets	8th
Male, 72	Traumatic lung laceration/ anterolateral thoracotomy	5th	No	Redo thoracotomy*	Antiplatelets and acenocoumarol for chronic atrial fibrillation	10th
Female, 38	LUL for lung cancer/ anterolateral thoracotomy	1st	No	Redo thoracotomy*	Technical (failure to achieve proper hemostasis)	7th
Male, 67	LUL for lung cancer/ anterolateral thoracotomy	1st	No	Redo thoracotomy*	Technical (failure to achieve proper hemostasis)	11th
Male, 71	RUL for lung cancer/ anterolateral thoracotomy	1st	No	Redo thoracotomy*	Antiplatelets	14th
Male, 48	Metastasectomy/anterolateral thoracotomy	1st	No	Redo thoracotomy*	Technical (failure to achieve proper hemostasis)	7th
Male, 60	Long standing neoplastic lung abscess/left pneumonectomy/ anterolateral thoracotomy	Day of surgery	Yes	Redo thoracotomy and hemostasis	Lung infectious disease (tricky local conditions during pneumonectomy)	8th

LUL, left upper lobectomy; RUL, right upper lobectomy. *, removal of blood clots and re-inflation of the collapsed lung.

reoperations are presented in Table 5. Reoperations were performed between the 8th and 29th postoperative day (median: 15.2 days), the earlier being performed for drainage of a post-pneumonectomy empyema. Reoperations for postoperative empyema resulted in serious prolongation of the hospital stay, since the median hospital stay from reoperation to discharge was 23 days.

Reoperation for bronchopleural fistula

Details regarding initial surgery and reoperations for bronchopleural fistula formation are presented in Table 6. Technical issues were implicated in bronchopleural fistula formation in 3 out of the 4 patients. Reoperations were performed between the 10th and 17th postoperative day (median: 12.5 days). Reoperations to control a bronchopleural fistula were associated with increase of the hospital stay (median time from reoperation to discharge: 18.5 days).

Reoperation to revise the thoracotomy incision or an ischemic musculocutaneous flap

Four patients underwent reoperation to repair the thoracotomy incision due to deep thoracotomy wound suppuration and dehiscence in three cases, lung herniation in one and venous congestion of a musculocutaneous muscle flap resulting in partial necrosis in the last one. Details regarding these operations are presented in Table 7. The median elapsed time from initial surgery to reoperation was 15.0 days. Discharge from the hospital was made possible within 14-21 days since the day of reoperation (median time from reoperation to discharge: 18.5 days).

Table 4. Details on reoperations performed for prolonged air leak.

Gender, age (years)	Initial operation/access	Day of reoperation	Site of air leak	Reoperation	Predisposing factor	Day of discharge after reoperation
Male, 74	RUL for lung cancer/ anterolateral thoracotomy	15th	Suture line/ interlobar fissure	Redo thoracotomy	Technical (failure to achieve aerostasis)	6th
Male, 69	RUL for lung cancer/ anterolateral thoracotomy	11th	Suture line/ interlobar fissure	Redo thoracotomy	Emphysema*	5th
Male, 59	RUL for lung cancer/ anterolateral thoracotomy	29th	Stapling line/ interlobar fissure	Redo thoracotomy	Emphysema*	4th
Female, 24	Right-side VATS bullectomy and pleurectomy for recurrent primary spontaneous pneumothorax	12th	Stapling line/ apex of the lung	Axillary minithoracotomy	Technical (failure to achieve aerostasis)	6th
Male, 15	Right axillary minithoracotomy bullectomy and pleurectomy for recurrent primary spontaneous pneumothorax	9th	Stapling line/ apex of the lung	VATS mobilization of the inferior pulmonary ligament and talc pleurodesis	Technical (failure to achieve aerostasis)	3rd
Female, 44	Left anterolateral thoracotomy for recurrent secondary spontaneous pneumothorax—bullectomy and pleurectomy	10th	Suture line/ superior segment of the left lower lobe	Redo thoracotomy	Emphysema*	14th

RUL, right upper lobectomy; VATS, video-assisted thoracic surgery. *, emphysematic changes were detected in preoperative chest CT scans and were noted in the pathology report of the resected specimen.

Table 5. Details on reoperations performed for postoperative empyema.

Gender, age (years)	Initial operation/access	Day of reoperation	Reoperation	Predisposing factor	Day of discharge after reoperation
Male, 33	Drainage of empyema and lung abscess/anterolateral thoracotomy	19th	Drainage of empyema and non-anatomic resection of the necrotic lung tissue	Lung and pleural infection Long ICU stay before initial surgery, drug abuse	36th
Male, 71	RLL/anterolateral thoracotomy	29th	Drainage of empyema and lung decortication	Lung infection (neoplastic lung abscess)	23rd
Male, 62	Drainage of traumatic hemothorax/anterolateral thoracotomy	8th	Drainage of empyema	Technical (ineffective chest tube drainage during initial thoracotomy resulting in multiple pleural fluid loculations)	10th
Male, 69	Left pneumonectomy/ anterolateral thoracotomy	10th	Drainage of empyema and insertion of irrigation system	Lung infection (large neoplastic cavitary lung lesion colonized with Candida Albicans)	24th
Male, 73	VATS lung and pleural biopsy	10th	Drainage of empyema and lung decortication	Lung infection (atypical mycobacteria)	8th

RLL, right lower lobectomy; VATS, video-assisted thoracic surgery.

Table 6. Details on reoperations performed for bronchopleural fistula formation.

Gender, age (years)	Initial operation/access	Day of reoperation	Reoperation	Predisposing factor	Day of discharge after reoperation
Female, 11	Drainage of lung abscess/ anterolateral thoracotomy	17th	Suturing of bronchial openings and intrathoracic muscle transposition to cover the surfaces of the lung abscess	Lung infection	14th
Male, 61	RUL en bloc with chest wall resection/anterolateral thoracotomy	10th	Drainage of empyema, reamputation of the bronchial stump and cover of the stump with a pedicled intercostal muscle flap	Technical (inappropriate application of bronchial stapler)	21st
Male, 55	Right intrapericardial pneumonectomy/ anterolateral thoracotomy	12th	Creation of open window thoracostomy	Technical (failure of bronchial stapling)	20th
Female, 57	Atpical resection of recurrent complex lung aspergilloma of the superior segment of the right lower lobe/ posterolateral thoracotomy	13th	Suturing of bronchial openings and intrathoracic muscle transposition	Technical (un-sutured bronchial openings)	17th

RUL, right upper lobectomy.

Table 7. Details on reoperations made to revise the thoracotomy incision or an ischemic muscle flap.

Gender, age (years)	Initial operation/access	Day of reoperation	Reoperation	Predisposing factor	Day of discharge after reoperation
Male, 63	LUL/anterolateral thoracotomy	15th	Deep thoracotomy wound infection and dehiscence—repair of thoracotomy incision	Lung infection (benign infected cavitary lesion of the left upper lobe) Long ICU stay before LUL	23rd
Male, 70	RUML/anterolateral thoracotomy	22nd	Deep thoracotomy wound infection and dehiscence—repair of thoracotomy incision	Lung infection (obstructive pneumonitis)	14th
Male, 73	Pleurectomy and bullectomy for recurrent secondary spontaneous pneumothorax/anterolateral thoracotomy	13th	Repair of lung herniation using synthetic mesh	Technical (loose pericostal sutures)	9th
Male, 65	Drainage of empyema and lung decortication/anterolateral thoracotomy	8th	Deep thoracotomy wound infection and dehiscence—repair of thoracotomy incision	Pleural and lung infection	32nd
Female, 61	Full thickness massive chest wall resection and reconstruction using the sandwich technique and musculocutaneous latissimus dorsi flap for recurrent breast tumor	16th	Flap ischemia and partial necrosis—debridement and application of Vacuum Assisted Closure system	Technical (venous congestion of the flap)	Transferred to plastic surgery department for further reconstructive surgery

LUL, left upper lobectomy; RUML, right upper and middle lobectomy.

Reoperation for persistent atelectasis of the remaining lung

Two patients underwent completion pneumonectomy for persistent atelectasis of the remaining lobe after left lower lobectomy which was performed for lung cancer in the 1st case and after left upper lobectomy performed for vanishing lung syndrome in the 2nd case respectively. Repeated fiberoptic bronchoscopies failed to expand the remaining lobe. Reoperations were performed the 5th and 9th postoperative day respectively. Both patients had fatal outcome since persistent atelectasis led to infection of the remaining lobe, with subsequent sepsis and multiple organ failure. Technical issues were detected as the cause of persistent atelectasis in both cases. The application of bronchial stapler too close to the origin of the left upper lobe in the 1st case of left lower lobectomy and the extensive mobilization of the left lower lobe during left upper lobectomy which had as result the twisting of the main bronchus at some body positions. Bronchomalacia was also present in the second case as a second contributing factor.

Reoperation to plicate the hemidiaphragm

Damage to the phrenic nerve during resection of a thymoma of the right cardiophrenic angle resulted in elevation of the right hemidiaphragm to the level of the 4th intercostal space. Reoperation to plicate the right hemidiaphragm through reopening of the anterolateral thoracotomy incision was obviated dyspnea development on minimal effort since the mobilization of the patient. Reoperation was made on the 11th postoperative day, resulting in almost immediate serious improvement of the clinical condition of the patient.

Reoperation for chyle leak

One patient underwent reoperation for chyle leak after the resection of a large bronchogenic cyst. Conservative treatment with total parenteral nutrition and octreotide administration for ten days failed to reduce chyle fistula output to less than 800 mL per day. Reopening of the thoracotomy incision was made on the 13th postoperative day. The site of chyle leak was well detected and sutured with multiple pledgeted "Π" sutures. Recovery of the patient was uncomplicated and he was discharged from the hospital after seven days.

Factors responsible for the development of complications which required reoperation for their management

Searching within the hospitalization notes and the notes of the initial procedure and reoperation of the 33 patients allowed us to detect some responsible factors responsible for the development of complications requiring reoperation. These factors were considered to be technical in 17 cases (51.5%), when initial surgery was employed for lung or pleural infections in 9 cases (27.3%), the recent antiplatelet drug administration in 4 cases (12.1%) and the occurrence of diffuse lung emphysematous changes in 3 cases (9.1%). Lung and/or pleural infections were well documented by cultures obtained from the bronchial tree, pleural fluid or the resected specimen.

Advanced lung emphysematous changes were found in 3 out of the 6 patients (50%) with prolonged air leak. The emphysema was obvious in preoperative chest CT scan and was also noted by the surgeon in the operation notes. The recent use of antiplatelets was detected in 4 out of the 9 patients who underwent reoperation for postoperative bleeding. Initial surgery in the presence of lung and/or pleural infection was recorded in 5 out of the 9 patients who were complicated with postoperative empyema and bronchopleural fistulas. Surgery for infectious lung disease was also found in one patient who was complicated with postoperative bleeding. The infection of the lung and pleural cavity during initial surgery were considered as the responsible factor for postoperative bleeding due to the particular local conditions during mobilization of the lung and dissection of the hilum. Deep wound infection and wound dehiscence occurred in three patients who were initially operated for lung and/or pleural infections. Long ICU stay before initial surgery was also recorded in two patients as a further contributing factor to infection.

In more than half of the cases various technical issues were considered to be the predisposing factors for the occurrence of a complication requiring reoperation, comprising of failure to achieve hemostasis or aerostasis, failure or inappropriate use of bronchial and parenchymal staplers, loose pericostal sutures, ineffective chest tube drainage, venous congestion of a latissimus dorsi musculocutaneous flap and extensive mobilization of the residual lobe.

Mortality of reoperations

Mortality of re-operations was 6.1% (2 out of the 33 patients) and it was associated with the need to proceed with completion pneumonectomy in both cases which developed postoperatively persistent atelectasis of the remaining lung resulting in infection of the remaining lung parenchyma. Both patients died of sepsis and multiple organ failure within a few days since the day of completion pneumonectomy procedure. In the rest 29 out of the 33 cases, early reoperation solved the problem allowing recovery of the patient.

Table 8. Incidence of operations requiring reoperation according to the initial surgical procedure performed in the 719 patients of the study.

Procedures	No. of operations	No. of patients requiring reoperation for complications	%
Lung parenchyma resection	228	17	7.4
Pleurectomy (with or without bullectomy)*	106	7	6.6
Resection of mediastinal tumors and cysts	55	2	3.6
Exploratory thoracotomy or thoracoscopy, lung and lung tumor biopsies	54	1	1.8
Drainage/decortication for empyema, drainage of lung abscess	37	3	8.1
Chest wall resection and reconstruction	22	1	4.5
Trauma (hemothorax, sternal fractures, rupture of hemidiaphragm)	11	2	18.2

*, pleurectomy/decortication procedures for mesothelioma are not included.

Type of procedures which were complicated with complications requiring reoperation

The higher rate of complications requiring reoperation was observed after surgery performed for trauma and lung/pleural infections, followed by lung parenchyma resection and pleurectomy (Table 8). Complications requiring reoperation for their management were necessary in 2 out of the 99 video-thoracoscopic procedures (2%). Procedures performed via median full or upper sternotomy, mediastinoscopies and mediastinotomies were not associated with complications requiring reoperation during the study period.

Discussion

Historical series on reoperation for postoperative complications after thoracic surgery report the rate of bleeding or clotted hemothorax to be the leading cause for reoperation. This accounts for 52-75% of all reoperations (3-5), with the exception of the series by Ermolov and Stonogin published in 1996, where rethoracotomy rate for intrathoracic bleeding was only 2.7% (11). Bronchopleural fistulas accounted for 17.8-25.5% of all reoperations in the above mentioned series (3-5). However, most of these series include patients who underwent thoracic surgical procedures since the early 60s. During the last five decades the evolution of general thoracic surgery with the ongoing use of minimally invasive techniques, the progress in surgical technology and biomaterials and the progress in lung isolation techniques made serious changes in general thoracic surgery practice. A range of procedures performed in the past are completely abandoned, other procedures are performed only through minimally invasive techniques, while aggressive surgery for locally advanced lung cancer became easier with the use of neo-adjuvant therapy and consequently the reoperation rate for complications in modern thoracic surgery needs reappraisal.

In the current study, the reoperation rate was higher (4.6%) than that reported in other series (1.2-3.7%) (3-7). In contrary, mortality rate of reoperations was lower (6.1%) when compared with the mortality rate reported in other published series (13.3-37.7%) (3,5,11). Fatal outcome in the present series was associated with the need to proceed with completion pneumonectomy for persistent atelectasis of the remaining lung after lobectomy. The use of completion pneumonectomy for failure of the residual lung to re-expand after primary surgery is reported by Montesano *et al.* [2002] to carry a high risk for fatal outcome (8). Guggino *et al.* reported also high mortality rate for completions pneumonectomies performed for complications of the initial treatment or as emergent/salvage procedure (12).

Reoperation is generally agreed to be necessary for the management of particular complications (i.e., bleeding, bronchopleural fistula, empyema), while it is debatable for others, especially in the management of prolonged air leak (1,2). In our practice we do not hesitate to reoperate if the prolonged air leak does not resolve with conservative treatment, if the lung fails to fully expand after discontinuation of the applied suction to the chest tubes and if the modern digital suction systems—such as the Thopaz system used in our unit—show a stable trend of the air leak during several (>5) days. One-way intrabronchial valves are not used in our practice to control a prolonged air leak, as their application with this indication still remains questionable and the success not well documented (13). The majority of patients with prolonged air leak are usually well recovered from the initial operation and otherwise fully ambulatory, making that way the complication very embarrassing for the patient. In addition, we have to outline that discharge of a patient with a Heimlich valve and other similar maneuvers are not an acceptable option in our policy (2,14,15). Reoperations for prolonged air leak with proper indications in the current study allowed fast recovery

and discharge of the patient from the hospital (median hospital stay after reoperation: 5.5 days). This fact is very important for patients who will undergo adjuvant treatment for malignancy or for patients undergoing surgery for benign conditions and need to return soon to their daily activities. According to Varela *et al.* [2005], prolonged air leaks are associated with significant morbidity and increased hospital cost and therefore aggressive surgical management should be performed with proper indications to shorten the hospital stay (16). According to the results of our study, bullectomy and right upper lobectomy are the most vulnerable procedures for prolonged air leak. Right upper lobectomy has increased risk for prolonged air leak because probably of the two interlobar fissures to divide and especially if the lungs exhibit emphysematic changes.

The surgical management of complications requiring reoperation is debatable among thoracic surgeons and hence the aim of the current study is not to support or to propose any strategy or technique of management. The study focuses mainly on the rate of complications requiring reoperation and on the detection of possible predisposing factors for reoperation. The possible different opinions, strategies and surgical techniques used to resolve the complication or even the appropriate time to proceed with reoperation are out of the scope of the current study and they are not discussed.

Technical failures during the initial procedures were detected to be the major predisposing factor for reoperation, accounting for half of the cases in the present series. Even though technical issues can be involved as the cause of reoperation in any case, the presence of some clinical conditions or the use of antiplatelet agents was found to be related in the development of complications which required reoperation. Lung emphysematous changes are a well know predisposing factor for prolonged air leak, while initial surgery for lung and pleural infections is involved in wound suppuration and dehiscence, postoperative empyema and the formation of bronchopleural fistula (2,17,18). Moreover, lung infections are responsible for difficult to manage local conditions (heavy adhesions, fragile tissues, enlarge bronchial vessels) within the operated hemithorax which predispose to technical failures during surgery. Failure of bronchial or lung parenchyma stapling, if not recognized during surgery, can lead to serious postoperative problems mainly that of prolonged air leak and bronchopleural fistula (1,2). Especially, inappropriate stapling is very important during VATS procedures, where the stapling line is quite difficult to be checked for air leak after re-inflation of the lung. Thoracotomy wound dehiscence following wound suppuration is an uncommon complication after general thoracic surgery procedures, which in their majority are clean operations. Thus, surgery for lung and pleural infections (clean-contaminated or contaminated operations) is the commonest cause for the development of thoracotomy wound suppuration and dehiscence. Ischemia of a muscle flap used to cover a chest wall defect is mostly dependent to technical factors during mobilization or fixation of the flap (19).

The ongoing use of antiplatelets in medicine in order to prevent thrombosis in various cardiovascular pathologies seriously affects hemostasis in surgery, even if they are discontinued five days before surgery. Discontinuation of the antiplatelets carries high risk of thrombosis, especially in the clinical setting of drug eluting stents into coronary arteries and hence the most common policy is the discontinuation of antiplatelets and their replacement for a short-time before operation by a bridging agent, such as low molecular weight heparins (20). However, despite this policy platelet function is not completely normal during surgery and non-surgical bleeding from any raw surface in the operative field can occur. Areas of adhesiolysis, pleurectomy, mediastinal lymph node dissection, thoracotomy wound and site of chest tube insertion are the vulnerable sites for bleeding and accumulation of blood clots within the chest in general thoracic surgery. In a recently published [2012] retrospective series by Stock *et al.*, the authors found that reoperation for bleeding rate was similar in patients who discontinued clopidogrel, either with the use of a bridging agent or without a bridging agent, as also in patients who underwent thoracic surgery on clopidogrel. However, in this series, general thoracic surgery performed under clopidogrel administration was related with increasing rate of postoperative blood transfusions (21). In our series, clopidogrel administration before surgery or re-administration after surgery was related with 4 out of the 8 reoperations for accumulation of blood clots within the hemithorax, where a site of active bleeding was not found during reopening of the thorax.

The main limitations of the current study are the retrospective design and the relatively small number of the included patients. In addition, the number of the included esophageal procedures is very low, not allowing conclusions for the specific complications of esophagectomy requiring reintervention (i.e., anastomotic dehiscence). Video-assisted lobectomies and thymectomies are not also included in the performed VATS procedures during the study period, which could possibly affect the low complications rate (2%) of thoracoscopic procedures observed in the study. On the other hand, with the exception of esophagectomies as well VATS lobectomies and thymectomies, the case-mix includes procedures from the whole spectrum of modern general thoracic surgery, allowing the extraction of safe conclusions concerning the type or complications requiring reoperation for their management in the contemporary practice.

In conclusion, the reoperation rate for the management of postoperative complications in the era of modern thoracic surgery is low and they are mostly observed after thoracotomy. Bleeding and clotted hemothoraces are the leading cause of reoperation and the use of antiplatelets, even if discontinued before surgery, is highly involved in the development of such complications. Infectious lung and pleura during the initial operation predispose to the development of postoperative empyema, bronchopleural fistula, wound suppuration and dehiscence. Emphysematic changes in the lungs predispose to the development of prolonged air leak. Despite the recognition of some predisposing conditions for major complications requiring redo-thoracic surgery to control, technical failures during the initial operation are the major source for the development of such complications. Completion pneumonectomy that is performed in the postoperative period as emergent procedure for the management of persistent atelectasis of the residual lobe is associated with high risk for fatal outcome.

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