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REVIEW
COMPETENCE IN INTERVENTIONAL PULMONOLOGY

Competence and training in interventional pulmonology

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ABSTRACT

Interventional pulmonology (IP) is experiencing a rapid evolution of new technologies. There is a need to develop structured training programs, organized in high volume expert centers in order to improve trainee education, and including the development of validated metrics for their competency assessment. Concerning teaching methods, a gradual progression from theory to practice, using new teaching techniques, including live sessions and low and high-fidelity simulation, flipped classroom models and problem-based learning (PBL) exercises would provide a training setting more suitable for our current need to improve skills and update professionals. Training programs should be learner-centered and competence-oriented, as well as being based on a spiral-shaped approach in which the same subject is addressed many times, from new and different perspectives of knowledge, ability, behavior and attitude, until the trainee has demonstrated a high degree of skill and professionalism. Furthermore there is a need to standardize the training programs as guide for physicians wishing to undertake a gradual and voluntary improvement of their own competencies, and assist those planning and organizing training programs in IP. The article includes a general part on core curriculum contents, innovative training methods and simulation, and introduces the following articles on the skills that the Interventional Pulmonologist must master in order to perform the different procedures. This monography should be considered a starting point that will evolve over time and results in better training for practitioners and better care for our patients. The task of establishing a trainee's competence to practice independently as an Interventional Pulmonologist remains the responsibility of the IP fellowship program director and faculty, who validate logbooks and assess competence for each procedure. These standards need to be reviewed and approved by national and International Scientific Societies and Healthcare Institutions with the aim to improve, disseminate and incorporate them in healthcare programs.

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KEY WORDS: Pulmonary Medicine - Bronchoscopy - Education - Competence.

Interventional Pulmonology (IP) is a subspecialty of pulmonary and critical care medicine that focuses on the evaluation and management of thoracic diseases, primarily involving the airways, lung parenchyma, and pleural space, using minimally invasive diagnostic and therapeutic procedures. IP is experiencing a rapid evolution of new technologies, with an emphasis on multidisciplinary care. The diversity of these procedures, and their application in patients with more complex conditions, is leading to the need for more specific training recommendations within this subspecialty. As patient safety and outcomes-based evaluation of clinical practice and procedures have become the priorities, the need for standardization in procedural training, that goes beyond pulmonary and critical care fellowships, must be considered. There is a need to develop training programs, organized in high volume centers of excellence, with curricula specifically designed to enhance patient safety and improve outcomes, in order to improve trainee education, including the development of validated metrics for their competency assessment. The development of IP has made the training programs of Specialty Schools no longer sufficient,[1, 2] not just in Italy but elsewhere as well. Over the past 20 years the number and complexity of interventional procedures has increased considerably, leading to recommendations for additional training after Specialty training.[3-9]

In specialty training the Core Curriculum envisages the acquisition of competency in basic diagnostic flexible bronchoscopy, but many schools are not even able to perform the entire training program and we are still lacking objective criteria by which we can assess the competency acquired by trainees who have completed the training. Further, there is no overall program including complex diagnostic procedures such as endobronchial ultrasound (EBUS), bronchoscopic navigation, thoracoscopy and operative procedures. The more complex interventional procedures are therefore acquired after Specialty training, often once the physicians are active practitioners, through training courses that are different for each professional. And there are no objective criteria to assess and certify the competency achieved by each trainee in the more complex interventional procedures. Modelled on the example of Ultra-Specialty disciplines such as Interventional Cardiology and Digestive Endoscopy, several international projects are underway to establish structured training and certification programs for IP as well.[3, 6]

In the USA, 37 new postspecialty fellowships in IP have been established since 2005, each one lasting 1 or 2 years. The Association of Interventional Pulmonology Program Directors (AIPPD) in collaboration with the American Academy of Bronchoscopy and Interventional Pulmonology (AABIP) and the American College of Chest Physicians (ACCP) have launched a program aimed at standardizing competencies and training of Interventional Pulmonologists based on the recommendations of the Accreditation Council for Graduate Medical Education (ACGME)[10]. In these training settings, the Program Director is responsible for organizing a structured syllabus, for ensuring the availability of suitable training tools, including simulation models, and for providing expert teaching staff and tutors (including being responsible for the constant assessment of staff performance); he/she will also be required to keep records of trainees' progress and acquisition of skills, evaluating their performance and keeping a record of complications, as well as being in charge of contacts with other teachers and with Scientific Societies, from whom he/she receives feedback on the quality of training and on the scientific evaluation of teaching methods adopted. For this reason, the Program Director must devote at least 50% of his/her time to aspects related to training in IP.[3, 4, 6, 7, 9]

The European Respiratory Society (ERS) has also established 2 programs:

• HERMES (Harmonizing Education in Respiratory Medicine for European Specialists) consisting in a yearly Multiple Choice Questionnaire covering all areas of Pulmonology. The Spirometry teaching program is the only one that also includes practical training and assessment. The ERS report on this program is available at www.ersnet.org/hermes;

• a program providing professional certification of competence in Bronchoscopy with EBUS, which was introduced in 2016. The aim of this project is to train qualified physicians so that they are able to perform EBUS independently and competently. This three-part training program will ensure that participants possess all the necessary knowledge and skills required to obtain ERS certification in EBUS (Figure 1).[11]

Another problem to be addressed relates to the teaching methods. Trainees are for the most part expected to learn through fairly ineffective methods, consisting in students sitting passively listening to frontal lessons, or in the traditional "see one, do one, teach one" method, which offers hardly any theoretical basis and very little practical experience. This is unjustifiable as a teaching program, since it is well-known that it is highly ineffective from a learning point of view and places the patient at risk of complications when the results are unsatisfactory. Novel education tools such as simulation, flipped classroom models and problem-based learning (PBL) exercises are transforming the traditional approach to knowledge delivery. A gradual pro-

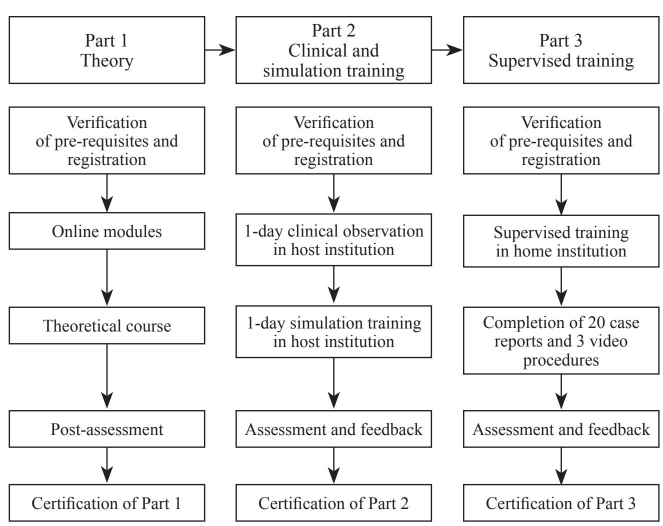

Figure 1.—ERS training program Endobronchial Ultasound (EBUS).[11]

gression from theory to practice, using new teaching techniques, including live sessions and simulation, would provide a training setting more suitable for our current need to improve skills and update professionals. The full development of a subspecialty in IP will include the acquisition not only of knowledge and skills, but also of the behaviors and attitudes described in the curriculum, including a high degree of personal and professional maturity, which is based on experience and takes time to acquire. Training programs should be learner-centered and competence-oriented, as well as being based on a spiral-shaped approach in which the same subject is addressed many times, from new and different perspectives of knowledge, ability, behavior and attitude, until the trainee has demonstrated a high degree of skill and professionality. The method proposed is based on a step by step approach, where the trainee undergoes a constant process of maturation and is offered opportunities to improve his/her professional skills.

Recent advances in the field of education research have highlighted the need to standardize both training programs and evaluation of trainees, based on measurable competency metrics rather than mere volume (*i.e.* number of procedures performed) or subjective assessments from mentors and supervisors.[12-25]

As we recognized that there is a gap between the fellowship programs in pulmonology and the real world, in 2010 we began to organize an academic postspecialty 1-year Master Course on IP. A Consensus Conference on the professional training and competence standards for IP was organized to come to an agreement on a core curriculum.

The report of the Consensus conference was published as an executive summary and is available in full in the website of the European Association fot Bronchoscopy and Interventional Pulmonology (EABIP). It proposes a Core Curriculum describing the professional profile of the Interventional Pulmonologist and the Training Process needed in order to achieve a level of competence that enables him/her to perform and manage – both independently and as a team member – all the main issues and procedures in IP. The aim of the document is to guide and support physicians wishing to undertake a gradual improvement of their own competencies, and assist those planning and organizing training programs in IP according to standardized criteria agreed upon by the scientific community.[26, 27]

This special issue includes a general part on core curriculum contents (Table I, Table II),[3,6] innovative training methods including simulation, and introduces a series of articles describing the knowledge, skills, and attitudes required for competency in each specific procedure. Also included are the teaching methods to be adopted, useful information sources, and the most appropriate qualitative and quantitative methods for the assessment of competence in each procedure.

The aim of this publication is to standardize minimum requirements for IP fellowship programs and Life-long learning (LLL). It offers organization guiding principles that can be followed on a voluntary basis, not as a strictly binding standard.

Modern training and assessment tools for IP

From the notion of training to the notion of competency

Professional competence in medicine means to make use — on a regular basis and in a sensible manner — of communication, knowledge, technical skills, clinical judgment, emotions, values and critical reflections in one's everyday practice in order to enhance the wellbeing of individuals and of the community.[18] Competence therefore includes knowledge (knows), clinical skills and capabilities (knows how to do), personal attitudes and behaviors (knows how to act). Psychologist George Miller, back in 1990, proposed a model for the assessment of clinical competence based on the layers of a virtual pyramid, integrating basic knowledge with clinical skills and personal skills into the actions performed.[28] Mehay *et al.* adapted the Miller triangle to include the knowledge, skills and attitudes domains of learning and thus called it "Miller's Prism" (Figure 2). Dent and Harden have added a fifth level called 'Mastery' that sits above 'Does' to make the distinction between one who can perform a skill with competence to one who can perform it in an expert or masterful way.

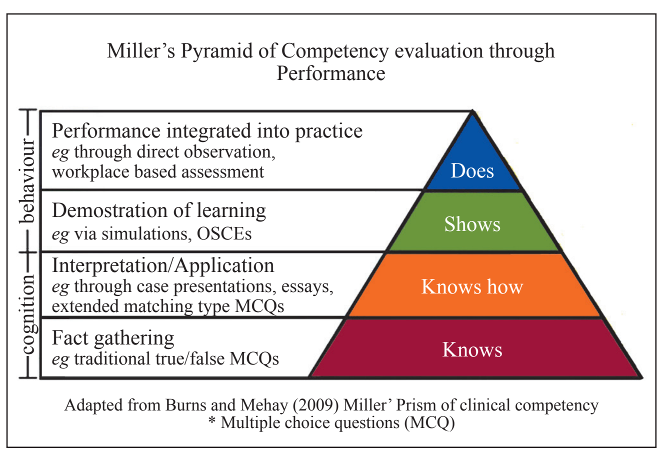

Figure 2.—Miller's Prism of Clinical Competence (also known as Miller's Pyramid).[28]

TABLE I.—*Program requirements for Graduate Medical Education in Interventional Pulmonology.**, [26, 27]

Basic requirements

- University Degree in Medicine and Surgery:
- trainee must be qualified to practice as a physician;
- trainee must have completed a Fellowship in Pulmonology or other Fellowship, such as Internal Medicine, Emergency Medicine, Thoracic Surgery and Anesthesiology and must have worked professionally for at least 5 years in a Respiratory Unit*.

General competencies

Basic technical and professional knowledge, skills, behaviors and attitudes:

- epidemiology of the pathologies pertaining to pulmonology;
- bronchopulmonary, pleural and mediastinal anatomy;
- physiology applied to airways obstruction and anesthesiology procedures;
- knowledge of clinical risk: monitoring and preventing postprocedural (diagnostic and/or interventional) side effects, adverse reactions and complications;
- recording/documenting the process of diagnosis and treatment using the appropriate tools and technologies.

Basic technical and instrumental knowledge, skills, attitudes:

- knowledge of instruments, including maintenance and problem-solving tasks;
- correct use of tools and devices appropriate for diagnostic/interventional procedures;
- monitoring and oversight of correct functioning of equipment, devices and tools used;
- management of machines providing mechanical ventilation;
- technological innovation and mastery of new machines (Health Technology Assessment – HTA).
- procedural quality control management: maintain and produce a comprehensive procedural log that includes underlying diagnosis, outcomes, diagnostic yield, and complications;
- equipment maintenance and procedural suite design;
- occupational Safety and Health Administration (OSHA) and infection control regulations and policies as they pertain to procedural suite design, ventilation, radiation physics and biology, as well as isolation and safety requirements related to the use of X-ray imaging equipment; laser physics and safety.

Medical knowledge and skills

- knowledge of the basic principles of anatomy, physiology and physics, as they pertain to the practice of IP;
- thoracic imaging procedures, to include CT, MRI, PET, thoracic ultrasound;
- principles of advanced airway, mediastinal and lung parenchyma imaging enhancement techniques: endoscopic MRI-EMN (Electromagnetic Navigation), radial and convex ultrasound and transthoracic ultrasound;
- knowledge of indications, contraindications, limitations, complications, techniques and interpretation of results of those diagnostic and therapeutic procedures integral to the discipline, including the appropriate indication for (and use of) screening tests/procedures, as well as the risks and benefits of alternative procedures;
- ability to achieve an accurate and in-depth evaluation of the patient, including the identification of specific risk factors for each procedure;
- evaluate and identify key aspects of a complex situation;
- formulate diagnosis of specific potential risk and of treatment intensity;
- choose the most effective intervention strategy based on the patient's pathology and clinical conditions;
- correctly identify, describe and communicate the significant outcomes of the procedures;
- ability to prevent and manage expected and unexpected mechanical complications of interventional pulmonary procedures, which may include:
    - simple and tension pneumothorax, hemothorax;
    - airway disruption, perforation, tear;
    - massive hemoptysis;
    - refractory hypoxia/respiratory failure;
    - injury to adjacent organs, *e.g.* esophageal perforation during percutaneous dilatational tracheostomy placement;
    - airway fire;
    - secondary tracheal stenosis (post tracheostomy) and secondary bronchial/tracheal strictures from laser/EC/mechanical trauma/anastomotic complications;
- ability to manage semi-intensive respiratory activity;
- identify, manage and prevent pulmonary infections;
- recognize one's own limitations and the limitations of the specialty or facility; refer patients appropriately to facilities possessing suitable instruments and competencies;
- medical legal issues and informed consent.

*Pursuant to Italian legislation Decree of the President of the Republic no. 484, dated 10/12/97, and Ministerial Decree HEALTHCARE 30-31/01/98 – item 11 of tables – validated without time limits pursuant to Legislative Decree 254, dated 28/07/2000).
This model is the result of a process of reflection and systematic reorganization of concepts and practices from experiences in "competence training," adopted in Europe as a training strategy; the model is based on European and Italian legislation and on several national/international experiences aimed at identifying common or innovative elements.

Table II.—*Specific competence in interventional pulmonology*[3, 6] *(knowledge, skills, attitude).*

Part A: disease-specific basic knowledge requirements	
Lung cancer and solitary pulmonary nodule	• Diagnosis, staging and natural history of thoracic malignancies to include lung cancer, mesothelioma, thymoma, lymphoma • Pathology of lung cancer • Indications, contraindications, limitations, complications, techniques, and interpretation of results of diagnostic and therapeutic procedures integral to the discipline, including the appropriate indication for and use of screening tests/procedures as well as the risks and benefits of alternative procedures • Collaboration among specialists in the management of lung cancer: 1) multidisciplinary thoracic tumor board; 2) undiagnosed mediastinal and hilar lymphadenopathy.
Malignant and non-malignant central airway disorders	• Malignant central airway disorders • Non-malignant central airway obstruction due to: • tracheal/bronchial obstruction secondary to, for example, granulomatosis with polyangiitis, postintubation/tracheostomy, tuberculosis, sarcoidosis, amyloidosis, recurrent respiratory papillomatosis, broncholithiasis, tracheal/bronchial malacia/excessive dynamic airway collapse secondary to relapsing polychondritis, Mounier-Kuhn Syndrome, COPD; • foreign bodies; • vocal cord disorders; • airway complications following airway surgery/lung transplant; • to include anastomotic strictures/granulation; • airway stent-associated granulation tissue; • extrinsic compression from, for example, goitre, mediastinal; • cyst, lymphadenopathy; • Pathophysiology and radiographic interpretation of central airway obstructions; • Strategy on endoscopic and surgical treatment.
Interstitial lung diseases and granulomatosis	• Classification, epidemiology, etiology, clinical and endoscopic diagnosis, treatment and follow-up of interstitial lung diseases • Radiographic (CT-Scan) interpretation of the main patterns of ILD and granulomatosis • Indication for interventional bronchoscopic diagnosis (BAL, transbronchial biopsy and needle aspiration, cryobiopsy) and for surgical biopsy
Pulmonary infections	• Classification, epidemiology, etiology, clinical and endoscopic diagnosis, treatment and follow-up of pulmonary infections • Radiographic and blood chemistry interpretation of pulmonary infections • Indication for interventional diagnosis (BAL, transbronchial biopsy and needle aspiration) • Management of critical phases of pulmonary infection
COPD and Asthma	• Pathophysiology, classification, imaging and treatment of severe COPD • Indications for the endoscopic treatment of emphysema • Pathophysiology and treatment of severe asthma • Differential diagnosis of asthma • Indications for the endoscopic treatment of asthma (thermoplasty)
Pleural diseases	• Parapneumonic effusion and empyema • Malignant pleural effusions • Malignant mesothelioma • Recurrent non-malignant pleural effusions (chylothorax, hepatic hydrothorax / effusions due to refractory congestive heart failure) • Pneumothorax • Pleural fistulas • Knowledge of differential diagnosis and treatment through non-invasive (radiographic imaging, thoracic ultrasound) and invasive procedures (medical thoracoscopy with parietal pleural biopsy and pleurodesis, pleural catheter placement: chest tube, small bore catheter, and implantable tunneled catheters, percutaneous pleural biopsy, VATS)
Part B: skills in diagnostic and operative procedures	
Flexible bronchoscopy and basic biopsy technique	• Flexible bronchoscopy and basic biopsy techniques: endobronchial biopsy, transbronchial biopsy, TBNA, ROSE, BAL, brushing
Endosonographic techniques	• Interventional endosonography (EBUS, EUS, EUS-B): Mediastinal and hilar lymph node sampling using convex endobronchial ultrasound
Bronchoscopic navigation	• Navigation, guided transbronchial biopsy (guided-TBB) for peripheral pulmonary lesions (PPL) and cryobiopsy for Interstitial Lung Disease (ILD): image-guided or computer-guided diagnostic bronchoscopy for evaluation of parenchymal opacities, of airway invasion *vs.* compression, and to guide biopsy: fluoroscopy, electromagnetic pulmonary navigation, EBUS-radial probe and cryobiopsy.

(To be continued)

TABLE II.—*Specific competence in interventional pulmonology*[3, 6] *(knowledge, skills, attitude) (continues).*

Operative bronchoscopy	• Rigid bronchoscopy with the following associated procedures: • Rigid core and mechanical debulking • Endobronchial ablative techniques using one or more of the following devices: laser, argon plasma coagulation, electrocautery, cryotherapy • Photodynamic therapy • Placement and removal of endobronchial stents (silicone, hybrid, dynamic) • Rigid sequential dilatation • Foreign bodies removal • Management of massive hemoptysis • Markers implant
Pleural procedures	• Medical thoracoscopy with parietal pleural biopsy and pleurodesis • Pleural catheter placement (chest tube, small bore catheter, and implantable tunneled catheters)
Thoracic echography	• Thoracic ultrasound to assess and guide interventions in the pleural space
Bronchoscopy in ICU, anesthesiology, and thoracic surgery	• Bronchoscope intubation in difficult airways • Management of endotracheal tubes, double lumen tubes and laryngeal mask • Management of tracheostomy tubes • Tracheobronchial aspiration to drain secretions • Diagnosis of pulmonary infiltrates, VAP and ARDS in ICU • Percutaneous dilatational tracheostomy placement and management • Use and integration of interventional procedures in the management of surgical interventions: mediastinoscopy, thoracotomy and lung resection, thoracoscopy and video-assisted thoracoscopy, surgical management of empyema, lung volume reduction surgery, lung transplantation, laryngeal/tracheal resection and reconstruction, tracheoplasty, suspension laryngoscopy, open surgical tracheotomy, pulmonary sequestration, and management of other malformations, cystic lesions, empyema • Clinical and surgical staging of lung cancer, Diagnosis and treatment of surgical complications: loss of airway integrity; anastomotic dehiscence, tracheobronchial/esophageal fistula, broncho-pleural/alveolar-pleural fistula; management of chest drainage
Pediatric bronchoscopy	• Skilled use of flexible and rigid bronchoscopy • Management of complications • Operative bronchoscopy for foreign body removal
Emergency in interventional pulmonology	• Bronchoscopic management of massive hemoptysis, foreign body, thoracic trauma, central airway obstructions and lesions, surgical complications • Pediatric thoracic emergency
New treatments in asthma and COPD	• Endoscopic treatment of emphysema and bronchial thermoplasty

It is fundamental that any training session (either in the classroom or in a practical setting), or any program aimed at updating specialized physicians be capable of involving all three elements (knows, knows how to do, knows how to act) by using the teaching tools and methods that are best suited to the task at hand, and which are capable of ensuring that trainees achieve the level of competence, as described above (Figure 3).

In this section we shall examine the various methodologies and the most effective evaluation tools: each will be described in detail in relation to its application in Interventional Pulmonology training programs.

Competency-oriented education

Training in the new and increasingly complex medical technologies, such as IP, calls for a radical change from the traditional teaching practices, which envisaged the trans-

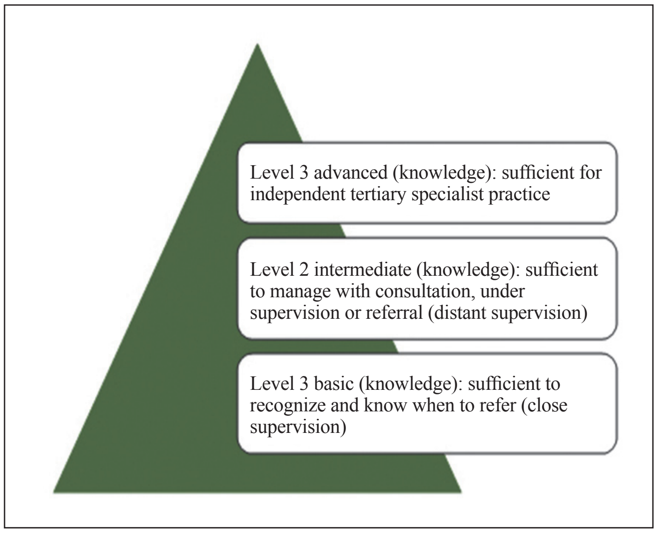

Figure 3.—Level of competency.

fer of the theoretical knowledge acquired by the trainee directly onto the patient. Such a pattern is nowadays considered both ethically and legally unacceptable, since it can place the patient at risk if the initial stages of the physician's learning curve have been unsatisfactory. Furthermore, the time a physician would need to learn the technique would risk becoming very long, since not enough procedures are performed on patients to meet the needs of trainee physicians.

Currently most training is provided through methods that are not very effective, consisting in the passive administration of frontal lectures and in the teaching method known as "see one, do one, teach one", with little theoretical background knowledge and equally little practical experience.

According to the more recent didactic methodologies, training in Interventional Pulmonology should be organized in 5 stages:[21]

1) theoretical stage with the use of more interactive teaching methods, such as flipped classroom, problem-based learning, live streaming, e-learning and blended learning;

2) practical stage using low and high-fidelity simulators (artificial models, animal models, virtual reality, practical sessions on cadavers);

3) practical stage on patients under supervision of a tutor, based on the specific learning curve associated with each procedure and on the individual trainee's predisposition;

4) quantitative and qualitative assessment of acquired competence and final certification;

5) life-long learning: continuing professional development is an important part of training programs, enabling physicians to constantly update their professional competence. It is also a need linked to the physiological loss in performance levels when training opportunities are lacking. An entirely new paradigm, Continuing Professional Development (CPD), has been proposed as a replacement for the existing Continuing Medical Education (CME) system.

Every stage of the learning process can and should be monitored according to specific evaluation criteria and tools (knowledge and skills-based assessment).

Practice centers or boot camps, where training is provided through a gradual process from theory to practice using live sessions and simulation can provide a form of training that is more in harmony with the current needs for improvement of competencies and continuing professional development.[29-30]

Learner-centered classroom model

General principles

"Tell me and I forget. Teach me and I remember. Involve me and I learn" by (Benjamin Franklin).

Many studies, both nationally and internationally, have shown that classroom training is more effective when it is interactive, favoring the active involvement of trainees.[31] If the students are the main focus of the training program (student-centered teaching, as defined by Colt *et al.*),[19] and characteristics such as flexibility, accessibility, capacity to adapt and cultural sensitivity are the basic pillars on which the training activity is constructed, the following aspects of student involvement are stimulated: 1) personal initiative; 2) search for solutions; 3) use of experimentation; 4) observation as a tool leading to theoretical elaboration.

In order for training to be able to express its full potential it is also necessary for students to understand clearly the aims of the training and for the overall training program to be sustainable, in terms of both resource allocation and sufficient generalizability. Learning must be gradual, multidimensional, structured, personalized, stimulating and as evaluable as possible.[20, 21]

Andragogy, also known as adult learning theory, was proposed by Malcom Shepard Knowles in 1968. According to Knowles, andragogy is the art and science of adult learning, thus andragogy refers to any form of adult learning. In the andragogical model it is central to consider adults as learners, subjects in learning, who have specific individual perspectives, and the teacher, who is considered a facilitator, consultant, change agent, fosters the development of self-directed learning and skills acquisition skills (Figure 4, Table III).[31]

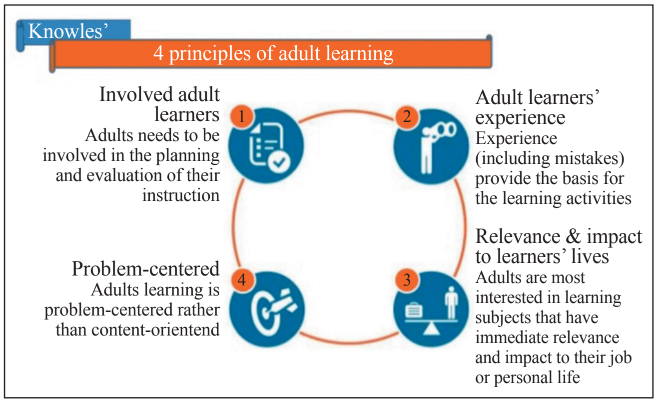

Figure 4.—Principles of Andragogy.[31]

Murgu *et al.* introduce the experiential learning theory. The experiential learning theory model addresses various learning styles and should be used for designing continuing medical education programs (Figure 5).[32]

The cardinal principles of this theory are:

- problem-based learning improves knowledge retention compared to traditional lessons;
- the overturned class model is preferred by students because it improves active learning;
- the checklist and tool evaluation are useful in providing immediate and objective feedback;
- implementation of space education strategies improves knowledge acquisition and retention after a live course.

TABLE III.—*The two models of the learning process.*[31]

Pedagogical	Andragogical
• Learner is dependent on teacher, who decides what should be learned, how and when; and whether it's been learned. • The experience of the teacher, textbook writer and AV constructor is what counts (the student's experience doesn't matter; his identity comes not from experience but from external sources: he's the son of X; lives at Y, goes to school at Z). So the backbone of pedagogy is transmission techniques. • Student readiness to learn is mostly a matter of age as he moves through the curriculum. • Orientation to learning is subject-centered: acquisition of content, organized in terms of curriculum. • Motivation to learn is through external pressures: parents, teachers, competition for grades and fear of failure.	• Learner is self-directing, but conditioned by schooling to dependency on teachers for learning, so she has to be re-oriented. • Adults are the richest sources of experience for one another: there's great variety of experience among 30+ year old (as there is not among 5-year old). But they can be locked into routinized ways of thinking, so may need help in becoming more open minded. An adult's identity is her experience, what she has done. So to devalue this experience is to devalue the adult as a person. • Readiness to learn is dependent on need to know or do something to meet some critical developmental life task more effectively. • Orientation to learning is problem-centered; so learning experiences have to be organized round critical life experiences. • The most powerful motivators are internal: a better quality of life; recognition; self-esteem; self-confidence, self-actualization.
Basic format: a content plan	**Basic format: process design**

• Students are isolated learners in competition for grades, an atomized mass before the authority of the instructor.
• It is the instructor's responsibility to cover all the content the student needs to cover the curriculum.
• And organize it in 5O-minute chunks, 3 per week, 13 weeks a term etc.
• The learning sequence is determined by the logic of the subject matter, not the readiness of the learners.
• The most effective means of transmission are lectures, AV presentations and assigned readings (or demonstration and drill, if skills are involved).
	• The instructor is a facilitator or resource person. But there are many other resource persons to call upon: the learner's peers; specialists in the community; media or computerized resources; field experiences, etc. –
	• Climate setting is crucial. The physical setting is important (and the typical classroom, with chairs in rows and a lecture podium up front, is singularly unsuited for learning). Learners should face one another, or sit in groups round tables. Far more important, however, is the psychological setting, especially in regard to the following:
	  • mutual respect between the facilitator and learners;
	  • collaboration (rather than competitive rivalry) among learners;
	  • trust of all involved;
	  • supportiveness: learners are treated with unqualified personal regard and organized into support groups;
	  • openness and authenticity are modelled by the facilitator, to enable learners to risk trying out new behaviors.
	• Learning is designed to be an adventure, laced with the excitement of discovery.
	• Humaneness and a caring social atmosphere are vitally important
	• Learner involvement is crucial:
	  • learners are committed to the plan to the extent that they've participated in the planning;
	  • learners have to help diagnose their own learning needs. Some kind of model of socially and organizationally needed competencies is required, for them to be able to spot gaps they need to fill;
	  • learners should participate in formulating their own learning objectives; this is best done through helping them produce learning contracts.
	• Learners must participate in the design of lesson plans, if their learning objectives, learning styles and problem-solving styles are to be accommodated.
	• Learners have to be helped to carry out their learning plans as per their contracts.
	• Self-direction requires participation in evaluation of one's work (and a major shift to qualitative methods of evaluation is in train, to make this more feasible).

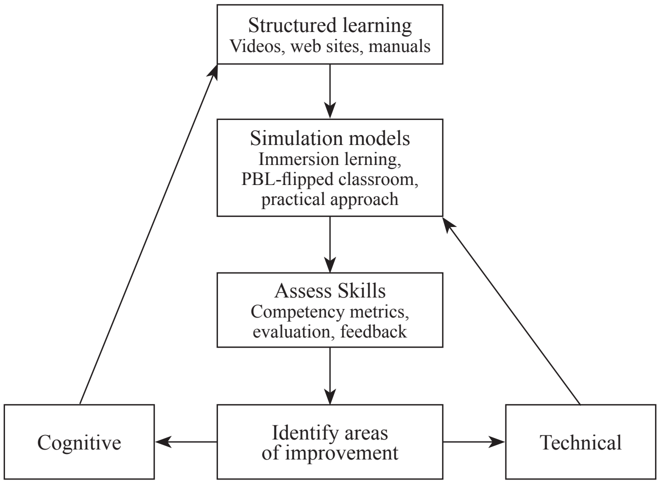

Figure 5.—Implementation of the flipped classroom model.[32]

For this reason, all methods based on the principle of active learning have the following requirements:

- the method must be agreed upon with students and match their training needs;
- the teacher must be transformed into a trainer/facilitator;
- a set of rules that all players have agreed upon and which they observe fully, in a context of stringent discipline;
- agreement over the fundamental importance of the "training contract" between trainers and trainees.

A further fundamental element, which will be decisive in ensuring the success of the activities, is the notion of "discovery" which enhances the trainees' mastery of new knowledge.[21, 33, 34]

Methods and techniques for the stage of theoretical and classroom training

Among the tools most useful in providing an interactive learning experience are those that make the most of web-based resources, such as teleconferences, e-books, websites and blogs, Apps, e-learning, learning objects, MOOC-Massive Open Online Courses, etc. These tools can make available in real time, "on demand" and on a vast scale, a huge variety of scientific materials, most of which are constantly updated.

E-learning platforms, the most popular of which is Moodle, allow trainers to organize their lessons and to create interactive systems that can be used in self-evaluation and remote evaluation as well. Massive Open Online Courses (MOOC) are university-level free access courses,

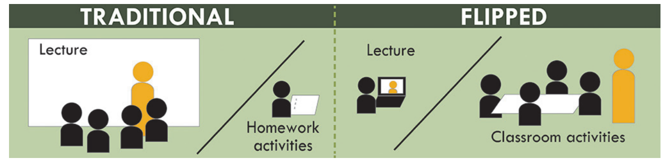

Figure 6.—Traditional *vs*. flipped classroom.

organized by major international universities. Then there are web-based structured courses which provide the basic theoretical notions required, including especially those available at www.bronchoscopy.org.

Among the main classroom techniques, the "flipped classroom" is a method that has been in use for many years, aimed at increasing trainees' productivity, especially during the hours that the students spend in what is formally defined as the classroom.[35] In this teaching model, traditional lectures can be provided to students online, so that they can read them in their own time, leaving actual student-teacher contact time for engaging in PBL and enquiry (Figure 6).[21]

In Problem Based Learning (PBL) the teacher presents a problem to the class and acts as a facilitator or mentor, rather than as the provider of solutions.[36] In medicine, these exercises help learners gain cognitive, technical and experiential skills in a patient- and learner-centric environment. One such model, the "Practical Approach (PA) to Interventional Bronchoscopy", is based on a four-box format which has been developed to complement traditional learning (Table IV).[21] This type of PBL helps learners think about the reasons for their actions and elaborate implementation strategies based on background information, relevant literature and personal experience.[37]

There are other tools that can support training programs, including the following:

- journal club, presentations given by groups of students and discussed by all;
- case presentations;
- research projects (with assessment);
- lessons in small groups;
- grand rounds, consisting in the presentation of cases and clinical activities to an audience of physicians and students, in the presence of the patient, who can answer questions, or who can be replaced by an actor simulating the patient's behavior;
- demonstrations of clinical skills and lessons;
- critical evaluation and EBM;
- reading the specialized literature.

TABLE IV.—*The four-box approach for problem-based learning.*[21]

Initial evaluation • Physical examination, complementary tests and functional status assessment • Patient's significant comorbidities • Patient's support system (also includes family) • Patient preferences and expectations (also includes family)	**Procedural strategies** • Indications, contraindications and expected results • Operator and team experience and expertise • Risk-benefits analysis and therapeutic alternatives • Respect for persons (informed consent)
Procedural techniques and results • Anesthesia and other perioperative care • Techniques and instrumentation • Anatomic dangers and other risks • Results and procedure-related complications	**Long-term management plan** • Outcome assessment • Follow-up tests, visits and procedures • Referrals to medical, surgical or palliative/end of life subspecialty care • Quality improvement and team evaluation of clinical encounter

Hands-on practical training

General principles underpinning training programs

There is a large component of procedures in Interventional Pulmonology. In training programs for this discipline practical training is therefore of crucial importance, *i.e.* practicing the different procedures before being allowed to perform them independently. How successfully this part of the training course is implemented, however, will depend very much on the methods and techniques used, as well as on the assessment and evaluation criteria applied during the course itself. The number of different procedures that all trainees need to become competent in is vast, and this could be risky for patients involved in the practical stage of training courses in Interventional Pulmonology; furthermore, the final assessment assigned to each trainee should not merely list the number of practical procedures performed, but rather provide a means of certifying the trainee's level of competence.[15, 16]

Training methods and techniques

The concept of "learning by doing on patent" can no longer be considered acceptable, especially when the procedures in question are invasive and risky for patients. Equally, the old approach of "see one, do one, teach one" is no longer sustainable. In recent years a more complex and multi-faceted approach has come into use, centered on the notion "see one, simulate many, do one competently" which can even be extended to include "teach everyone." This has led to the development of simulation tools capable of enhancing and facilitating practical hands-on learning, as well as extending the opportunity of training to all students.[38]

Historically, the apprenticeship model has been used to teach trainees how to perform flexible bronchoscopy through practice on patients. Not only does this training model induce learner anxiety, but trainees also acquire different experiences, depending on the individual patients and preceptors they encounter.

Leaving the training experience to chance introduces significant variability in the training and can result in some physicians being inadequately trained in basic procedural skills. Although generally considered to be a safe procedure, bronchoscopy can be associated with severe complications, including respiratory failure and death. The presence of trainees during bronchoscopy may lead to increased complications, thereby placing the burden of procedure training on our patients by impacting their comfort and safety. In addition, non-diagnostic procedures resulting in the need for "repeat" procedures may also be considered a specific complication in the training environment. As new techniques are developed, the practicing physician is faced with learning new skills without the opportunity or time for dedicated training or proctored procedures that have clearly defined learning objectives. In recent years linear endobronchial ultrasound with transbronchial needle aspiration (EBUS-TBNA) is a technique that is rapidly changing the bronchoscopic diagnosis of many chest diseases but can be challenging to learn, even for experienced bronchoscopists.[39] Demand for training is high and may be ideally suited for the use of simulator programs, which often form a component of the courses.[40]

Simulation, as a training and learning method for both technical and non-technical skills (NTS), offers a wide range of opportunities for practical application in medicine.[41] Training systems using simulation exercises for medical or nursing trainees (or physicians and nurses in LLL) include a number of technological devices and task trainers, ranging from tools relating to specific technical skills to high- fidelity simulators capable of reproducing physiological functions and alterations or multi-systemic pathologies affecting the human body.

High and low fidelity simulation in IP

Fidelity refers to the realism of something. Within simulation, fidelity refers to two things: 1) the realism of the mannequin. These are arbitrarily termed low-, mid/medium- or high-fidelity mannequins; 2) the realism of the environment in which the simulation takes place. For participants to fully engage in simulation, they need to willingly suspend their disbelief. One way of helping this is through the fidelity of the environment or simulation suite; making the suite appear like the clinical environment you are trying to emulate is very important. With the development of wireless mannequins, it is now possible to perform *in situ* simulation, within the practitioner's own environment. Low fidelity simulation uses inanimate mechanical airway models,[42] into which actual bronchoscopes can be inserted and bronchoscopy skills can be practiced. Advantages of low fidelity simulation include low cost and the ability to use standard bronchoscope equipment. Disadvantages include reduced realism and the risk of damaging the bronchoscope.

Low fidelity mannequins are artificial anatomical models, made in plastic, or made from cadaver parts (either animal or human). Their advantage is undoubtedly that they provide a perfect reproduction of the anatomy, but they do not allow for the reproduction of situations or complications that may occur in a living model, such as respiratory and cardiac movements, coughing, muscle spasm, hemorrhage. To overcome these limitations, and thanks to an increasingly advanced technology, models defined as high fidelity have been introduced. In the field of bronchial endoscopy, for example, high fidelity simulators not only provide a perfect reproduction of the anatomical structure of the bronchial tree and its adjacent structures, they allow practitioners to reconstruct a real-life environment including cardio-respiratory movements, coughing and resistance against the introduction of the scope. They further allow for the simulation of clinical scenarios and complications so as to test the trainee's ability to manage complicated procedures (such as, for example, the removal of foreign bodies) or the management of complications (for example, iatrogenic bleeding or desaturation).[20, 43-49]

Both groups, low and high-fidelity simulators, have advantages and disadvantages. There is still no evidence to prove that either one or the other type of simulation is superior to the other. So, at present, they are considered complementary.[50]

Low fidelity simulators: physical models

Silicone-based and plastic-based models, such as the Laerdal Airway Management Trainer (Laerdal, Stavanger, Norway) and the Life/form "Airway Larry" (Nasco, Fort Atkinson, WI, USA), consist of a head, upper airway, larynx, and basic tracheobronchial tree. These models can be used for performing laryngotracheal intubation and airway management exercises, including bronchoscopy-guided endotracheal intubation. The CLA Broncho Boy (CLA, Coburg, Germany) and AirSim Advance Combo bronchi (© TruCorp® Ltd, Belfast, UK) also have a torso and/or a detailed tracheobronchial tree (to the level of the first segmental bronchi) and can be used for learning and evaluating rigid bronchoscopy skills (Figure 7). They enable trainees to practice the entire procedure, starting from the insertion of the bronchoscope, through the nose or the mouth, to the inspection of all 19 pulmonary segments.

A model with a bifurcation (Model TEUS-B) was developed for EBUS-TBNA training.

The Ultrasonic Bronchoscopy Simulator (KOKEN CO. LTD, Tokyo, Japan) can be used not only for ultrathin bronchoscope insertion training and transbronchial biopsies, but also for endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) and radial EBUS training.

ArtiCHEST® trainer (©MIMEDA GmbH, Heidelberg, Germany) is a simulator that offers physicians a wide range of simulation exercises on bronchoscopy procedures, including TBNA and EBUS-TBNA. Accurate s.r.l. produces several types of simulators for use in Interventional Pulmonology: an ultrasound trainer for thoracentesis and thoracoscopy which allows practitioners to develop and improve their skills in using ultrasound to identify and guide needles and catheters in patients with pleural effusion; an advanced mannequin for the management of airways in the adult (Figure 8).[51-56]

Trainees may use clinical bronchoscopes and other accessories, or disposable tools such as aScope™ 4 (Ambu A/S, Ballerup, Denmark) which is equipped with a smaller screen and a reduced image quality, but is very practical for training programs, due especially to its low maintenance costs (Figure 7).

Simulation on animal model and on cadaver

Simulation on animal models *in vivo* or on individual organs, such as for example pig lungs, either frozen or preserved under plastic lamination, is extremely useful in all endoscopy procedures.

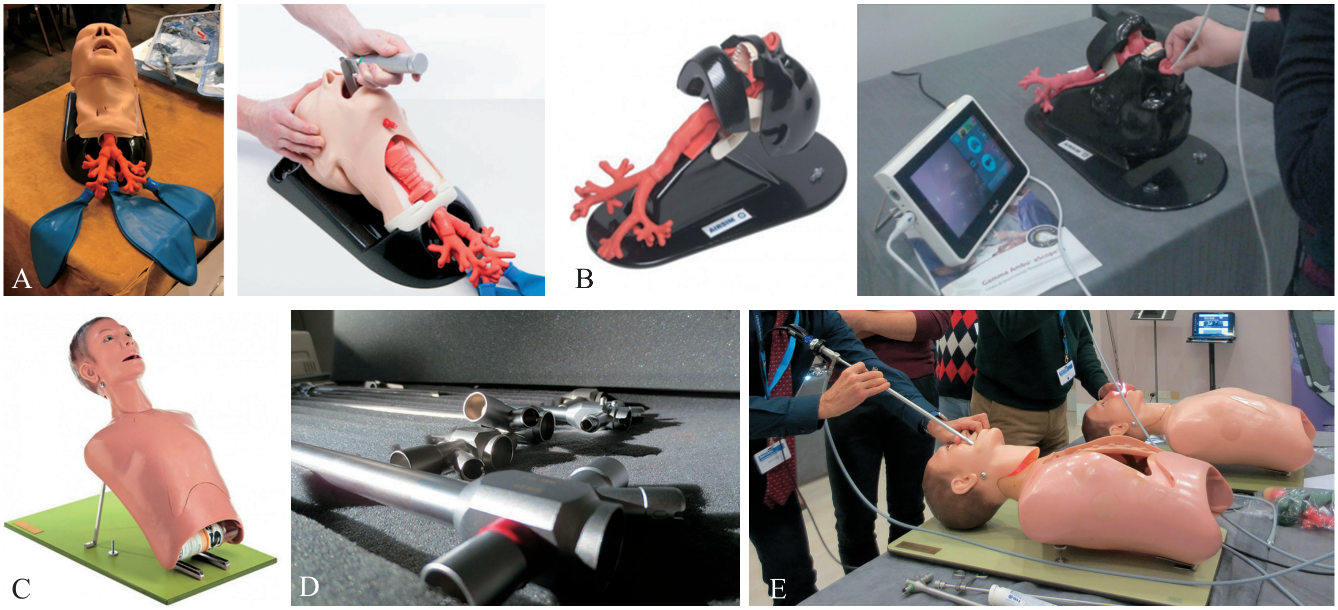

Figure 7.—Low fidelity simulators: physical models. A) AirSim Advance Combo Bronchi; B) AirSim Bronchi model with aScope 4 Broncho; C) broncho boy; D) rigid bronchoscope; E) rigid bronchoscopy on a mannequin.

Many institutions have used animal models for airway management courses, bronchoscopy CME courses for EBUS and Interventional pulmonology techniques, and during pulmonary and IP fellowship training. Advantages of wet lab models over computer models include increased realism and giving the learners the opportunity to use the actual bronchoscopy equipment. Disadvantages of the wet lab models are the ethical issues associated with the use of animals for research and education, the cost of the highly trained personnel required to ensure safe and humane handling of the animals, and the potential for damage to the expensive bronchoscopes. There are no publications comparing wet lab simulation with high fidelity and low fidelity simulation for bronchoscopy training. There is a need to evaluate the cost/benefit ratio and compliance with national legislation.

The use of embalmed human or animal cadavers in the teaching of bronchoscopy has been well documented, and the exercises have been studied by Ram *et al.* who have shown that they allow trainees to develop the psychomotor skills needed to perform a bronchoscopy correctly; they are also useful for physicians who want to keep their skills in practice. But the use of cadaver models does present considerable limitations, essentially in that they are incapable of reproducing the exact situation or the complications of a living being, such as the movements of the cardio-respiratory system, coughing, muscle spasm, hemorrhage. Furthermore, the donor is required to have given his/her consent when still alive and the procedure on cadaver material can only be performed in specifically authorized centres.[17, 57]

High fidelity virtual reality simulators (task trainer)[58-68]

A computer-based bronchoscopy simulator that could be used for bronchoscopy training was first described in 1999. This “PreOP Endoscopy Simulator” (HT Medical Systems, Rockville, MD, USA) consists of a proxy flexible bronchoscope, a robotic interface device and a computer with monitor and bronchoscopy simulation software. The learner inserts the proxy bronchoscope into the nasal passage of a robotic interface device, the proximal end of which is shaped to look like a human face. The interface device monitors the movements of the proxy flexible bronchoscope and creates resistance forces, simulating the forces experienced during an actual bronchoscopy procedure. The proxy bronchoscope tracks the manipulations of the bronchoscope (including the tip control lever, suction button, etc.) and the computer software creates computer-generated images of the airway on the monitor to simulate a realistic virtual bronchoscopy experience. These studies confirm that metrics based on computer simulator performance can differentiate between operators of different experience and skill levels, for both basic and complex

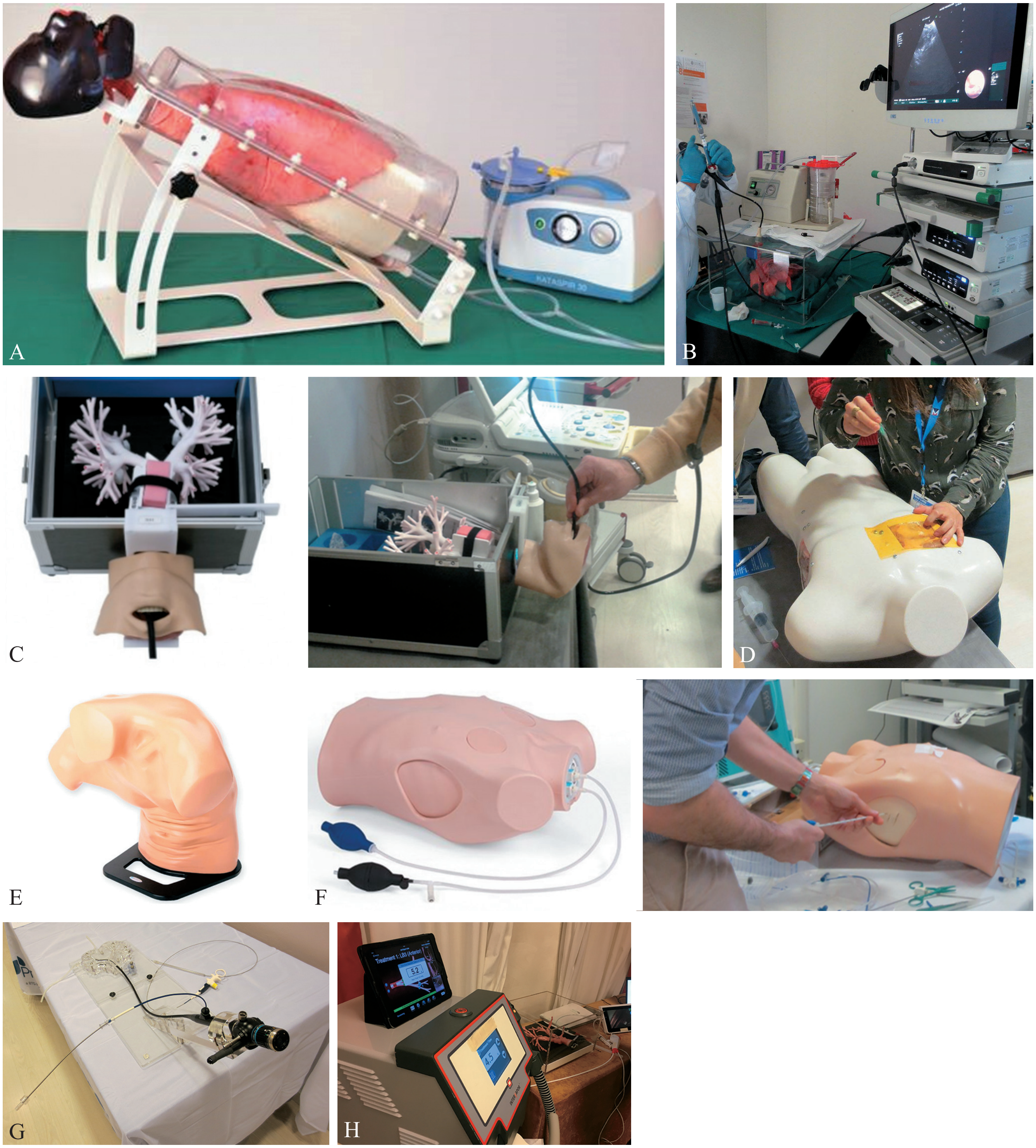

Figure 8.—Low fidelity simulators. A) ArtiCHEST® trainer; B) EBUS on pig lungs; C) EBUS bronchoscopy simulator; D) mannequin with window for pig rib cage; E) trainer for medial scapular thoracentesis echo-guided; F) ATLS trainer for thoracic drainage, pneumothorax and ultrasound techniques; G) simulator for the application of endobronchial valves; H) simulator for InterVapor endoscopic thermal ablative treatment for emphysema.

bronchoscopy procedures. Superior clinical skills are associated with better performance on simulators.

A newer version of the simulator renamed the "AccuTouch Endoscopy Simulator" is now owned and distributed by CAE Healthcare, Montreal, Canada. The "EndoVR™ Interventional Simulator" (CAE Healthcare) is a training device for both traditional bronchoscopy and EBUS. The BRONCH Mentor (3D Systems Healthcare, Littleton, CO, USA) consists of a hardware platform with a touch screen, a modified bronchoscope and ultrasound endoscope, tools such as an EBUS needle, which are used in the training and evaluation of bronchoscopies. The trainee navigates through the 3D virtual anatomy and the computer generates realistic images in real time, as the trainee guides the bronchoscope through the airways.

Trainees can practice flexible bronchoscopy on dozens of simulated cases, including patient management, inspection of airways, endobronchial and transbronchial tissue sampling, EBUS-TBNA, and much more. There is also a less expensive portable model called Bronch Express. The new European Guidelines on Endoscopic Ultrasound recommend that pulmonologists be competent in both EBUS and EUS, but unfortunately, there is no simulator that includes a software for EUS training. Both the AccuTouch Endoscopy Simulator and the GI-BRONCH Mentor systems have the ability to incorporate gastrointestinal endoscopy modules into the system, which may be advantageous in some centers where cost sharing between departments is possible.

AirwaySkills (Auckland, New Zealand) has recently marketed a less expensive, lighter virtual reality simulator to be used in bronchoscopy training, but the absence of a force-feedback in the interface permits users to advance the tool to its maximum even without a guide. And the absence of a work channel means that it is not ideally suited for Interventional Pulmonology training.

Lastly, surgical science (Gothenburg, Sweden) is currently developing a software for bronchoscopy to be implemented on their virtual reality simulator EndoSim®.

Among thoracic ultrasound devices, SonoSim® (SonoSim, Inc, Santa Monica, CA, USA) is a simulator that provides good teaching experiences, since it includes an ultrasound diagnosis function based on real pathologies and cases.

Some studies confirm that metrics based on computer simulator performance can differentiate between operators of different experience and skill levels, for both basic and complex bronchoscopy procedures. In a recent study we found that trainees with presimulation EBUS-STAT scores above 80/100 did not show any significant improvement after virtual reality training, suggesting that this score represents a cut-off value capable of predicting the likelihood that simulation can be beneficial.[69]

Superior clinical skills are associated with better performance on simulators. Studies suggest that learners do acquire skills while practicing on simulators, as assessed by the simulator devices themselves. It has also been demonstrated that short-term learning gain occurs during 1-day introductory bronchoscopy courses with a focus on very specific cognitive information and bronchoscopy technical skill learning.

Some procedures performed during bronchoscopy — such as bronchoalveolar lavage, endobronchial biopsies/brushings, and conventional TBNA — require mastery of a tactile skill, or dexterity, which is difficult to simulate on a computer. TBNA and endobronchial biopsies on high fidelity simulators, in particular, have been found to lack realism. Fortunately, there are alternative low fidelity simulation models with perceived better realism that can be used, until the high-fidelity simulator technology improves. Transbronchial biopsy is the bronchoscopy sampling technique most associated with complications.

Bronchoscopy simulation could allow for repetitive practice of low-volume procedures or critical clinical scenarios. It is recognized that simulation scenarios can be created to teach very specific procedural aspects and to provide an element of control until the learner has demonstrated a basic level of competency. After this milestone has been achieved, additional elements of a given scenario can be added to reproduce the real-life distracters that call upon other skills which the learner needs to deploy in order to avoid chaos in a procedure. Examples of critical clinical scenario simulation already in use are wet lab and computer simulation models for practicing the management of patients with massive hemoptysis even in a non-technical skill simulation (Figure 9).

Non-technical skill training (NTS)

Technical skills are necessary but not sufficient to maintain high levels of performance over time. In 1999, the ACGME identified 6 core competencies residency programs required to teach: interpersonal and communication skills, professionalism, patient care, systems-based practice, practice-based learning and improvement, and medical knowledge. The Joint Commission in 2011 and 2012 identified failures in communication, human factors, and leadership as the most common issues as root causes in sentinel events. Adverse events in health care

Figure 9.—High fidelity virtual reality simulators (task trainers). A) Bronch Express; B) Bronch Mentor; C) EndoSim®; D) EndoVR ™ Interventional Simulator; E) ORSIM®; F) SonoSim®; G) Vimedix; H) Broncho-X.

have found that many underlying causes originate from failures in non-technical aspects of performance rather than a lack of technical expertise.[70] NTS are the cognitive and interpersonal skills that underpin effective team work: it is estimated that around 70-80% of healthcare errors can be attributed to a breakdown involving these skills. NTS are part of the human factors agenda. "Human factors" is an umbrella term which analyses how healthcare professionals interact with everything in their working environment, such as clinical guidelines, policies and procedures, equipment and stress management. NTS specifically examine the interaction of team members (liveware to liveware).[71-77] These skills are trained in crew resource management (CRM) courses in civil aviation, oil exploration, nuclear power and recently in anesthesia, emergency medicine and surgery. Errors more frequently observed in operating theaters were: 1) surgeon's failure to inform anesthetist; B) failure to anticipate events during complex procedure; C) failure to monitor other team activities; D) consultant distracted from making a decision by problems reported from another operating theatre; E) failure to brief own team; F) failure to discuss alternative procedure; G) hostility and frustrations owing to poor team coordination; H) failure to debrief operation to learn from situation; I) failure to establish leadership for operating room team; L) unresolved conflicts between surgical team and anesthetists. These are errors very common also in interventional pulmonology that have to be considered in a comprehensive training program in IP.

Interdisciplinary emergency clinical simulations are frequently used to educate surgical residents in leadership, teamwork, effective communication, and infrequently performed emergency surgical procedures. Simulations could be conducted in the operating room, intensive care unit, emergency department, ward or simulation center. Examples of these scenarios included a postoperative pulmonary embolism, pneumothorax, treatment of an acute myocardial infarction, gastrointestinal bleeding, anaphylaxis with a difficult airway, fires in the operating room, and pulseless electrical activity arrest. Sessions with a surgical role required the surgical residents to perform a procedure during the session (*e.g.*, cricothyrotomy, chest tube, and central venous catheter or access). Nicksa *et al.* using a SimMan 3GS to educate surgical residents in technical and nontechnical skills to simulate high-risk clinical scenarios, showed a significant improvement of performance after non- technical skill simulations: communication score increased from 3 to 3.71 (P=0.01), leadership score increased from 2.77 to 3.86 (P<0.001), teamwork score increased from 3.15 to 3.86 (P=0.007), and procedural ability score increased from 2.23 to 3.43 (P=0.03). There were no statistically significant improved scores in PGY 2 decision making or situation awareness. A modified Oxford Non-Technical Skills (NOTECHS)[78] 10 scale (score range, 1-4) was used to assess surgical resident nontechnical performance. The session was lasting 15 to 20 minutes. All simulation sessions were followed by 30- minute debriefings with real-time feedback. During the first 10 minutes, the participants reflected on the experience and their thoughts on the simulation; in the remaining 20 minutes, videos were viewed (if available) and the simulation team provided feedback, facilitated discussion, instructed on areas of knowledge as needed, provided insight, and encouraged participant self-reflection. There are very few experiences in Interventional pulmonology but the scenarios are similar to surgery including emergencies such as bleeding, pneumothorax, foreign bodies, central airways disorders, severe respiratory failure, difficult airways.

Assessment tools for accreditation and certification

Competency is deemed acquired when a person can demonstrate his/her proven ability to use knowledge as well as personal, social and methodological skills and abilities, in a situation related to his/her profession or in research, and benefit from such knowledge and skills in further personal and professional development.

Ever since the early 20th century (1933) in the USA there has been a system certifying professional know-how and competence: Board Certification. Since 2001 a time limit has been introduced to the validity of this certification, which now needs to be renewed within 6 to 10 years. The aim is to inform patients, protect their safety, improve the quality of healthcare. ACGME (Accreditation Council for Graduate Medical Education) guarantees the quality of the education content of training programs in every different specialty and subspecialty, as well as the qualitative and quantitative professional standards that every physician is required to achieve and maintain in order to be certified.[79]

There are specific tools that can be used to assess physicians' basic knowledge (an element of the practitioner's competencies) and their skills, tools such as the Multiple Choice Questionnaires approved by the Joint Royal Colleges of Physicians Training Board (JRCPTB) and the Objective Structured Clinical Examination (OSCE).[80]

As far as the field of Interventional Pulmonology is concerned, specific validated tools have been developed by AIPPD/AABIP, by Prof. Henry Colt (www.bronchoscopy.org) and by the Copenaghen Centre.[14, 77, 81-83]

Knowledge assessment

The Multiple Choice Questionnaire elaborated by AIPPD members has shown that it is capable of measuring the ability of physicians to take decisions based on training and practical experience, for in a practical exercise (assessing 4 study groups of first and last year specialty students in Pulmonary and Critical Care Medicine, as well as students and trainers of the additional yearly program in Interventional Pulmonology) their results yielded statistically significant differences.[84] Of course, in order for assessment tools to be able to evaluate competence in such a highly complex discipline, they must take into consideration all the subjects included in the recommended training curriculum for Interventional Pulmonologists, and this means all the knowledge specifically related to the different pathologies and to the range of procedures (Table V).[84]

Savran *et al.* developed and validated a specific theoretical test in endosonography including endobronchial ultrasonography (EBUS) and esophageal ultrasonography (EUS) with real-time aspiration of the lymph nodes.[81]

Skill assessment

As far as procedural skills are concerned, criteria used in the evaluation are both quantitative (volume of procedures performed, including establishing a minimum number) and qualitative (self- evaluation test and evaluation by a supervisor). While the number of performed procedures may rightly be considered an indirect indicator guaranteeing competence, it is also true that different practitioners have different learning curves, *i.e.* they do learn by performing procedures, but they do so at different speeds. Therefore, absolute numbers, even when they are high, may not be a guarantee of competence from a qualitative point of view. The assumption, in any case, is that the more a physician performs a procedure, the better he or she will be. However, precise data describing the learning curve for single procedures are difficult to obtain. And, as we have seen, it varies from person to person. It is fundamental that the trainee physician creates he/she own logbook, documenting all cases he/she has observed or assisted with, including pictures and video, as well as the basic case history and biopsy findings. It will then be possible to measure and monitor outcomes and performance quality, and to provide feedback to the trainees' directly, rather than relying solely on expert opinion, volume requirements, or other surrogate markers. Such a system could be combined with volume requirements and other didactic instruments.

Quantitative skill assessment

Precise data describing the learning curve for procedures are difficult to obtain as there is significant variability of the rate of skill acquisition. Sufficient volume to learn a skill may vary widely between individuals. For this reason the International and National Societies proposed empiric number of supervised procedures to reach competence and the minimum procedures per year required to maintain competency (Table VI).[85]

Qualitative skill assessment

Validated tools for qualitative skill assessment represent the cornerstone of competency-based programs and allow continuous feedback highlighting improvements and further opportunities for improvement.

The following is a list of workplace-based assessments approved by GMC and JRCPTB, and used in this curriculum:

Table V.—*Disease-specific knowledge in procedural Interventional Pulmonology. Source: Validation of an interventional pulmonary examination.*[84]

Disease-specific knowledge	IP procedural knowledge
Physiology as applied to:	• Procedures for pleural disease
• large airway obstruction (malignant and benign, asthma, COPD);	• Percutaneous pleural biopsy
• pleural disease;	• Diagnostic bronchoscopy
• jet ventilation;	• EBUS/electromagnetic navigation/narrow-band imaging
• anesthesia, sedation and analgesia;	• Therapeutic bronchoscopy
• complex airway disorders;	• Rigid bronchoscopy/ablation procedures/foreign body retrieval/ endoluminal therapies
• malignant central airway obstruction;	• Endobronchial brachytherapy
• nonmalignant central airway obstruction.	• Cryotherapy
Comprehensive evaluation and management of patients with:	• Photodynamic therapy
• thoracic malignancies;	• Balloon tracheoplasty/bronchoplasty
• lung cancer (including early detection/screening and staging);	• Tracheobronchial stents
• other intrathoracic malignancies;	• Bronchial thermoplasty
• intrathoracic manifestations of malignancy;	• Tracheostomy/transtracheal oxygen
• hemoptysis/stridor;	
• pleural diseases;	
• surgical interventions;	
• amyloid/foreign body removal/pap;	
• endoscopic therapeutic approaches to COPD and asthma;	
• image-guided or computer-guided diagnostic and therapeutic bronchoscopy.	

EBUS: endobronchial ultrasound; IP: interventional pulmonology; PAP: pulmonary alveolar proteinosis.

Table VI.—*Summary of published guidelines for numbers of procedures required in IP training.*

Type of procedure	BTS	TSANZ[85]	ERS/ATS	ACCP	AIPO
Flexible bronchoscopy	50*	200/12-20	NR	100/25	100/100
Rigid bronchoscopy	-	-	20/10-15	20/10	NR
TBNA		20	25/NR	25/10	NR
AFB	-	20/20	Long learning curve	20/10	NR
EBUS	-	50/20	40/25	50/20	NR
TTNA/B	-	-	10/5-10	10 aspirates, 10 cores/10	NR
LB	-	-	>20/10-15	15/10	NR/30
EES/APC	-	-	10/5-10	15/10	NR
EBCT	-	-	10/5-15	10/5	NR
Airways stents	-	-	10/5-10	20/10	NR
EBBT	-	-	5/5-10	5/5	NR
PDT	-	-	10/5-10	10/5	NR
PT	-	-	5-10/10	20/10	NR
TTOT	-	-	5/5	10/5	NR

Number of supervised procedures needed according to the different societies. The first number represents the minimum training required and the second (when present) the minimum procedures per year required to maintain competency.
TBNA: transbronchial needle aspiration; AFB: Autofluorescence bronchoscopy; EBUS: endobronchial ultrasound; TTNA/B: transthoracic needle aspiration and biopsy; LB: laser bronchoscopy; EES/APC: endobronchial electrosurgery and argon-plasma coagulation; EBCT: endobronchial cryotherapy; EBBT: endobronchial brachytherapy; PDT: photodynamic therapy; PT: percutaneous tracheostomy; TTOT: transtracheal oxygen therapy.
*The authors suggest at least 50 procedures under direct supervision and 50 under indirect supervision.

- mini-Clinical Evaluation Exercise (mini-CEX);
- Case-Based Discussion (CbD);
- Direct Observation of Procedural Skills (DOPS);
- Acute Care Assessment Tool (ACAT);
- multi-source feedback (MSF);
- multiple consultant report (MCR);
- audit assessment (AA);
- patient survey (PS);
- teaching observation (TO).

Workplace-based assessments should be recorded in the trainee’s e-Portfolio.

An objective evaluation of a practitioner’s skills can be done through DOPS (Direct Observation of Procedural Skills). A DOPS is an assessment tool designed to assess the performance of a trainee in undertaking a practical procedure, against a structured checklist. The trainee receives immediate feedback to identify strengths and areas for development. In addition to the general DOPS form available on the JRCPTB website, there are 2 DOPS forms specific to Respiratory Medicine — one forchest drain insertion/management and the other for fibre-optic bronchoscopy — which are also available on the website.[86-90]

Two instruments were studied and validated for the assessment of basic bronchoscopy skills: the Bronchoscopy Skills and Tasks Assessment Tool (BSTAT) and the Bronchoscopy Stepwise Evaluation Tool (BSET).[91]

The BSET tests a learner’s knowledge of a series of specific maneuvers designed to facilitate bronchoscope handling; it comprises a global rating scale and a rating of the proper execution of the specific maneuvers. The Bronchoscopy Skill Assessment Tool (BSTAT) assesses basic bronchoscopic anatomy knowledge, skill in maneuvering the bronchoscope through the bronchial tree and ability in performing tasks such as biopsy or bronchoalveolar lavage, and the identification of common airway pathologies.

BSTAT can be found at http://bronchoscopy.org/ downloads/tools/BSTAT, is designed to measure the skills of a bronchoscopist performing a diagnostic bronchoscopy and is comprised of 8 sections. The first 2 assess the operator’s knowledge of segmental anatomy, along with his/her ability to enter each segment. One section assesses whether the procedure was performed with the bronchoscope well-centered, avoiding excessive airway wall trauma, and another evaluates the operator’s posture, hand positions and equipment handling. Another section is a measure of how well the operator performs 2 standard maneuvers (entering RB-4, 5 and 6 and then LB-8, 9 and 10 on demand); the next section asks the operator to perform a standard diagnostic task; the possible tasks include bronchoalveolar lavage (BAL), bronchial brushing, endobronchial lung biopsy, transbronchial lung biopsy or transbronchial needle aspiration. The 2 final sections deal with the recognition of airway secretions and mucosal abnormalities; each consists of reviewing a slideshow of 10 color bronchoscopic images on a desktop monitor and selecting the correct description for each from a list. The BSTAT has a maximum score of 24 and can also be graded on a letter scale for users familiar with an A-F grading system.

The BSET has been specifically designed to measure performance on the Bronchoscopy Step-by-Step exercises (http://bronchoscopy.org/downloads/posters/StepByStepPoster.pdf). These exercises, elaborated by the same working group, are a series of graded training maneuvers that direct the learner through the incrementally difficult moves of bronchoscopy; the learner begins by practicing passage through the oral or nasal orifice to the larynx, followed by navigating central, lobar and segmental airways. The BSET is comprised of 2 sections. The Bronchoscopy Global Rating Scale (BGRS) assesses the operator's general bronchoscopic skills while performing the exercises; it is divided into 4 subsections focusing on bronchoscope manipulation, body posture and hand positions, identification of anatomy and the ability to perform specific exercises. The Bronchoscopy Exercises Rating Scale (BERS) measures the proper performance of each step-by-step exercise; it is divided into 3 subsections, relating to: 1) larynx, upper and central airway exercises; 2) lobar bronchial exercises; 3) segmental bronchial exercises.

The Ontario Bronchoscopy Assessment Tool (OBAT) assesses not only technical proficiency in bronchoscopy but also all clinically relevant aspects of bronchoscopy from pre-procedural planning to postprocedure documentation. The OBAT was designed to be sufficiently brief to be used in a clinical setting and sufficiently simple to be used by experienced clinical teachers with minimal additional training.[92]

For more complex procedures, the following DOPS have been validated:

- EBUS Skill Assessment Tool (EBUS-STAT): this is a 10-section assessment tool incorporating anatomy, equipment handling, and computed tomography and EBUS image interpretation. The EBUS-STAT is a 10-section assessment tool designed to objectively and systematically evaluate the technical skill and relevant knowledge of an operator performing convex-probe (CP) EBUS-guided TBNA. Created as a component of the Bronchoscopy Education Project, it can be used alone or in addition to other learning tools, reading materials, and simulation- based educational sessions to document the gradual acquisition of knowledge and skills in learners training to become competent EBUS-TBNA operators. The EBUS-STAT can be scored while observing an operator perform CP EBUS-TBNA in a patient or simulated environment. Of the 10 items, items 1 to 7 test technical skill, and items 8 to 10 use a 25-image slideshow to test computed tomography (CT) and EBUS image and pattern recognition, anatomic orientation, and correlation. The first seven items are tested in the procedure suite or simulation center, whereas items 8 to 10 can be completed using a computer monitor. (http://bronchoscopy.org/downloads/tools/EBUSTAT Checklist and Quiz question).[93]
- EBUSAT (EBUS Assessment Tool): the assessment tool was developed by a group consisting of two respiratory physicians, a thoracic surgeon, and a professor of medical education, all with considerable experience in performance, teaching, and validation of endoscopic ultrasound and other procedures. The tool was designed according to the original format for "objective structured assessment of technical skills," in which each item is rated on a scale from 1 to 5, with descriptive anchors in the middle and at the ends, and re-coded into a score from 0 to 4 points. Six items were designed to assess knowledge of the mediastinal anatomy, by requesting the operators to identify six anatomic landmarks: lymph node stations 4L, 7, 10L or 11L, 10R or 11R; the azygos vein; and lymph node station 4R. Four items related to the technical skills necessary to handle the scope and perform TBNA were defined: insertion of the endoscope, positioning of the transducer, use of sheath, and use of needle. Finally, two items were added to allow assessors to give their overall opinion on anatomic orientation and biopsy sampling, respectively;[94]
- the Endoscopic Ultrasonography Assessment Tool (EUSAT): used in EUS-FNA for mediastinal staging. A study by Konge *et al.* shows the EUSAT can distinguish operators' performances according to their level of experience, and the result appears to be reproducible;[82]
- UGSTAT was validated in 2013. UGSTAT (Ultrasound-Guided Thoracentesis Skills and Tasks Assessment Test) was devised following the Guidelines of the British Thoracic Society as a tool to evaluate the teaching of thoracic ultrasound before clinical practice. It consists of a questionnaire with a score on a scale of 100, which can be administered to learners with different levels of experience in thoracic ultrasound procedures, from beginners to intermediate levels and even to advanced level thoracic ultrasound practitioners.[95]

Other DOPS specific for Interventional Pulmonology currently awaiting validation:

- Bronchoscopy Skills and Tasks Assessment Tool for Transbronchial Lung Biopsy and Transbronchial Needle Aspiration (BSTAT-TBLB/TBNA);
- RIGID-TASC;[96]
- Chest tube-STAT;
- IBV-STAT.

Therapeutic and patient care skills can further be evaluated using the mini-Clinical Evaluation Exercise (Mini-

CEX). This tool evaluates a clinical encounter with a patient and its purpose is to provide an indication of competence in skills essential for good clinical care such as history taking, physical examination and clinical judgment. The trainee receives immediate feedback to aid learning. The mini-CEX can be used at any time and in any setting when there is a trainee and patient interaction, and an assessor is available (Table VII, VIII).

The following tools are used to evaluate general skills:

- Multi-Source Feedback (MSF): this tool offers a method of assessing generic skills such as communication, leadership, team work, reliability, across the domains of good medical practice. It provides for the objective and systematic collection of performance data and feedback relating to a trainee, derived from several colleagues. Raters are individuals with whom the trainee works: they include doctors, administration staff, and other related professionals. The trainee will not see the individual responses given by raters; the results will be given to the trainee by his/her Educational Supervisor;
- Case-Based Discussions (CbD): this tool assesses the performance of a trainee in his/her management of a patient; the aim is to provide an indication of competence in areas such as clinical judgment, decision-making and application of medical knowledge in relation to patient care. It also serves as a method to document conversations about — and presentations of — cases by trainees. The CbD should include discussion on a written record (such as written case notes, out-patient letter, discharge summary). A typical exchange might occur when presenting newly referred patients in the out-patient department;

Table VII.—*Knowledge and skills assessment strategies.*

It is assumed that the number of procedures performed is an indirect indicator of the "core competence" achieved
Practitioners learn procedures at different speeds, *i.e.* each has a different learning curve; in some physicians, absolute numbers, even when they are high, may not be a guarantee of acquired competence
Skills may be assessed objectively by means of DOPS
In any case, if and when this is possible, the training curriculum should envisage a minimum number of procedures to be performed during the training course (below which competence is not considered achieved)

Table VIII.—*Overall quality assessment of competence in medicine.*

MCQ (multiple choice questionnaires)
Case-based questionnaires, on appropriate decisions
DOPS
Assessment of maneuvers on mannequins
Assessment of procedures under supervision

- Patient Satisfaction Questionnaire (PSQ): this tool provides an evaluation of a learner's professional competence as perceived by patients. It gives information on the learner's communication and relational skills, and on the patient's perception of the learner's professional competence.[80]

The Respiratory Medicine SAC has suggested that evaluations should be carried out as follows:

- a minimum of 6 mini-CEX and/or CbD per year of training, as educational tools helping trainees achieve the competencies required for the particular stage of training;
- at least 2 MSFs, one at the beginning and one near the end of training;
- six bronchoscopy DOPS during the four-year single specialty training in Respiratory Medicine;
- seven bronchoscopy DOPS during the five-year dual training program in Respiratory Medicine and GIM.[80]

Transition from training to practice on patients

Transition to practice (TTP) programs were developed in the field of general surgery in order to provide a 1-year experience to postspecialty physicians enabling them to develop their independent decision-making processes, so that they can become autonomous in performing operative procedures, and so they can acquire practical management skills; the programs also offer them the opportunity to benefit from periodical reviews of their performance and their clinical outcomes. At present newly qualified specialists in surgery have less confidence in their ability to perform surgical procedures and do not feel fully competent in performing many common procedures in an entirely independent manner.

The key elements of this postspecialty experience are: to ensure the learner can act independently; to guarantee the presence of a senior surgeon acting as mentor, to ensure clinical responsibility; to provide a flexible program based on the evaluation of past experience and future objectives; to enable trainees to acquire practical skills and clinical outcome measurements.[97, 98]

Continuous professional development or lifelong learning

Continuing education is part of a training process that is intended to offer practitioners an ongoing and gradual maturation. It is also necessary, since a professional who does not undergo in-service training updates will experience a loss in performance levels.

An entirely new paradigm of continuous professional development (CPD) has been proposed, as a replacement for the conventional continuing medical education (CME) model. CPD includes several distinct characteristics. It focuses on lifelong learning that is based on the needs of individuals, as opposed to the needs of large learner groups, and involves the use of a range of learner-driven and learner-centered education and training methods. CPD is offered in venues that extend beyond traditional lecture halls and conference rooms, and uses a variety of learning formats and blended methods to achieve optimal results.

Clinical practice locations and simulated environments are well suited to the delivery of CPD. Furthermore, CPD is more comprehensive in scope than traditional CME, and can be used to address not just the clinical domain but also to practice management, leadership, teamwork, administration, and a host of other professional activities. Another important approach that can be used to offer practicing surgeons effective education and training involves the use of practice-based learning and improvement (PBLI).

Teaching tools are different from those used in initial training experiences. They focus on the learner's individual experience and facilitate his/her autonomous discovery of new knowledge, the importance of which was demonstrated in aviation training experiences (Table IX).[97]

Boot camp and structured courses

Practice centers or boot camps, where training takes place through a gradual process from theory to practice, using live sessions and simulation, may provide a training approach that is more in harmony with current needs to improve competence and continuous professional development.[99]

A European model of a Boot Camp is the new facility of IRCAD (Research Institute against Digestive Cancer) in Strasbourg. IRCAD was founded in 1994 within Strasbourg's University Hospital and it carries out research on digestive cancer as well as developing telematic and robotic systems. The field in which it has especially distinguished itself is training for Minimally Invasive Surgery, within the EITS (European Institute of TeleSurgery). Several years ago, IRCAD established a Boot Camp that included other disciplines as well, and provided space to some multinational healthcare product enterprises such as Medtronic-Covidien, Intuitive Surgical and Storz. Another European Centre fully equipped for the simulation in Interventional Pulmonology is the JMC Simulation Unit in Copenhagen: https://www.rigshospitalet.dk/english/contact-us/Pages/default.aspx.

Medical training is changing in Italy, too, and several new simulation centers have been established, to provide training both for students and for specialist practitioners. One of the first simulation centers to be opened in Italy is the one at the Mediterranean Institute for Transplants and Therapies (Istituto Mediterraneo per i Trapianti e Terapie ad Alta Specializzazione, ISMETT), based in Palermo. Other simulation centers are located in other parts of the country, most of them specialized in Emergency Medicine, Surgery, Interventional Medicine and the Management of the Critical Patient. Among these there are two training centers dedicated to IP in Florence and Ancona, where two Master courses are organized.

In the Boot Camp in IP events organized in Florence and Nuoro (Simannu Centre) the purpose is to adopt the recommendations shared in a selected group of pulmonologists with different levels of competence and different training objectives and includes the following session: 1) interactive theoretical session (flipped classroom); 2) case based discussion with the support of digital tools; 3) hands on practice on low and high-fidelity simulators; 4) final assessment of the competence.

TABLE IX.—*Theoretical/practical training methods in interventional pulmonology.*

Handbooks and atlases on the mediastinal anatomy, including instructions on tissue sampling procedures
Theoretical lessons (using Flipped classroom and Case discussion methods) on: indications, contraindications, instruments, organization of the endoscopy room, description of procedures
Live sessions
E-learning and e-mobile learning: Multimedia resources
Training supported by virtual reality simulation on: knowledge of anatomy, acquiring manual dexterity in bronchoscopy and tissue sampling procedures, examination of clinical cases (GI BronchMentor, BronchPilot i-Pad, Simbionix Express, EndoVR Accurate, Ultrasonic Bronchoscopy Simulator)
Use of mannequins and plastic models in simulating procedures in order to learn and improve coordination (using video systems for tutoring and the most recent disposable bronchoscopes)
Simulation on animal models *in vivo* or on individual organs, such as porcine lung, fresh, frozen or preserved under plastic lamination.
Training on patients under supervision, until trainees have achieved both quantitative and qualitative competency
Attending sessions in the endoscopy room
Continuing education by means of national and international publications
Taking part in clinical risk audits

TABLE X.—*Quantitative and qualitative assessment of procedures in IP.*

Procedure type	• Quantitative assessment for achieving competence/maintenance	Qualitative assessment
Flexible bronchoscopy and basic biopsy technique		
Diagnostic bronchoscopy with biopsy	• 100/50: ERS/ATS • 50: BTS • 200/12-20: TSANZ[85] • 100/25: ACCP	• MCQ • Case-based Questionnaire • Simulated assessment • DOPS: B-STAT, B-SET[91] • Video or direct supervision of procedure with the patient **Outcome assessment:** • Evaluation of diagnostic yield and complications: at least 85% diagnostic sensitivity for biopsies; • Operators shall ensure that sufficient diagnostic material is obtained to allow phenotyping and genotyping of tumors where appropriate (ROSE)
TBNA	• 25/NR: ERS/ATS • 25/10: ACCP • 20: TSANZ[85]	• MCQ • Case-based Questionnaire • Simulated assessment • DOPS: B-STAT, B-SET[91] • Video or direct supervision of procedure with the patient Outcome assessment: • Evaluation of diagnostic yield and complications: at least 85% diagnostic sensitivity for biopsies; • Operators shall ensure that sufficient diagnostic material is obtained to allow phenotyping and genotyping of tumors where appropriate (ROSE)
Interventional endosonography (EBUS, EUS, EUS-B)		

EBUS-TBNA	• 50 procedures, after at least 100 flexible bronchoscopies and 5 TBNAs: CCG
	• 40/25: ERS-ATS
	• 50/20: ACCP
	• 50/20 TSANZ[85]
		• MCQ
		• Case-based questionnaire
		• DOPS (EBUS-STAT, EBUS-SAT)[93,94]
		• Assessment on patient:
		  • Balloon and needle set-up in all cases
		  • Ability to pass scope through vocal cords in ±90% of cases
		  • Ability to image lymph node in question in ±90% of cases
		  • Ability to pass TBNA needle through wall of trachea/bronchus into node in ±80%
		  • Typical procedure time: 30–40 min
		• ERS-EBUS Board *Certification Methodology* based on verification of pre-requisites and registration, supervised training in home institution, completion of 20 procedures and 3 video procedures (www.ersnet.org).

EUS-FNA and EUS-B-FNA	• 20: ERS	• MCQ
		• Case-based questionnaire
		• DOPS (EUSAT)[82]
		• Assessment on patient:
		  • Ability to visualize lymph node in question in ±90% of cases
		  • Ability to pass TBNA needle through wall of esophagus into node in ±80% of cases
		  • Sensitivity for carcinoma in ±75% of cases
		  • Typical procedure time: 30–40 min

Navigation, guided transbronchial biopsy (guided- TBB) for peripheral pulmonary lesions (PPL)		
RADIAL EBUS	20/20 TSANZ[85]	MCQ Case-based questionnaire DOPS: Creation of a specific STAT (similar to EBUS -STAT) Outcome measures: Correlation between the image and the final histology in > 75% of cases (data to be recorded in the Logbook) Sensitivity for malignancy: 60–70% Typical procedure time: 30–40 min Safety: < 1% bleeding, pneumothorax, infections

(To be continued)

TABLE X.—*Quantitative and qualitative assessment of procedures in IP (continues).*

Procedure type	Quantitative assessment for achieving competence/maintenance	Qualitative assessment
Electromagnetic pulmonary navigation and virtual bronchoscopy navigation	• 20/20 CCG	• MCQ • Case-based questionnaire • DOPS: Creation of specific STAT (like EBUS - STAT) Outcome measures: correlation between the image and the final histology in >75% of cases, to be recorded in the Logbook: • Sensitivity for malignancy: 60–70% • Typical procedure time: 30–40 min • Safety: < 1% - bleeding, pneumothorax, infections
Transthoracic pulmonary biopsies	• 10/10: ACCP • 10/5-10: ERS/ATS	• MCQ • Case-based questionnaire • DOPS
Cryobiopsy for Interstitial Lung Disease (ILD)		
Cryobiopsy	• Trainee shall be in attendance on at least 10 procedures performed by expert bronchoscopists • (ACCP) • Trainee shall perform directly, as first operator, at least 10 procedures under supervision of an expert bronchoscopist • Trainee shall be in attendance on a session with a major complication of bleeding and tension pneumothorax Competence maintanance: • 5 – 10 procedures/year	• MCQ • Case-based questionnaire • DOPS on simulator and patient (cooperation among bronchoscopists, anaesthetists, nursing staff) Outcome measures: • Percentage of biopsies taken every procedure • Percentage of complications, in all procedures • Outcome of complications
Operative bronchoscopy procedures		
Rigid Bronchoscopy	• 20/10-15: ATS/ERS • 20/10 ACCP	• MCQ • Case-based questionnaires • DOPS (RIGID TASC96), on simulator, animal and patient Outcome assessment: • Ability to pass instrument into the trachea on first attempt in >90% of cases without • significant hypoxic periods • Injury to teeth, gums or larynx on < 2% of cases • Therapeutic results (% of disobstruction, symptom improvement, quality of life)
Laser	• >20/10-15 ATS/ERS • 15/10 ACCP	• MCQ • Case-based questionnaires • DOPS (RIGID TASC96) on simulator, animal and patient Outcome assessment: • Relief of symptoms in > 85% of cases • Complication rate (haemorrhage, hypoxaemia, perforation, cardiac events): <5%
Electro/APC	• 10/5-10 ATS/ERS • 15/10 ACCP	• MCQ • Case-based questionnaires • DOPS (RIGID TASC[96]) on simulator, animal and patient
Cryoablation	• 10/5-10 ATS/ERS • 10/5 ACCP	• MCQ • Case-based questionnaires • DOPS (RIGID TASC[96]) on simulator, animal and patient
Airways Stents	• 10/5-10 ATS-ERS • 20/10 ACCP	• MCQ • Case-based questionnaires • DOPS (RIGID TASC[96]) on simulator, animal and patient Outcome assessment: A significant improvement in the score of breathlessness (as measured by an appropriate instrument) should be demonstrated in at least 80% of cases • Patency achieved demonstrated by a picture of pre- and post-procedure endobronchial appearance and chest X-ray in all cases • Typical procedure time (not including laser or other ablation technique) for stent: 20–30 min • For fistulae, there should be reduction in fistula sequelae in 80% of cases • Complications should occur in <20% of cases. These include stent displacement, • cough, mucus impaction, granulation tissue at stent ends, infection and perforation of airway walls.

(To be continued)

TABLE X.—*Quantitative and qualitative assessment of procedures in IP (continues).*

Procedure type	Quantitative assessment for achieving competence/maintenance	Qualitative assessment
Pleural procedures		
Pleural drainage	• 10/3 CCG	• Management of patient comfort and complications • Case-based questionnaires, including evaluation of correct decision-making • DOPS (e.g. UGSTAT and EUTAT, TUBE-iCOMPT (the Chest Tube Insertion Competency Test: a 5-domain 100-point assessment tool in line with British Thoracic Society guidelines and international consensus)[95,101,102,103,104] **Outcome assessment:** A. volume of examinations performed B. % of complications
Thoracoscopy and talc poudrage	• 10 per year, although this might be fewer in those centres where there is a high throughput of other pleural procedures.	A novel and dedicated assessment tool for VATS is proposed also for HT.[105] A detailed log book should be kept by the trainee, to include data such as: • video recording of procedures. **Outcome assessment:** A detailed log book should be kept by the trainee, to include data such as: • >80% sensitivity for malignancy. • 1 month post thoracoscopy. • >70% success rate of pleurodesis.
Thoracic ecography		
Thoracic ultrasound	• EFSUMB (European Federation of Societies for Ultrasound in Medicine and Biology)[106] suggests that the trainee should: • observe at least 25 thoracic ultrasound examinations • perform under supervision at least 100 examinations on normal patients • 50 examinations on patients with pleural effusions • 25 thoracenteses	• Questionnaires MCQ • Case-based questionnaires, with decision- making process • Assessment tools (UGSTAT, TUBE-iCOMPT[95, 102]). LUS-OSAUS has been recently proposed as an assessment tool that can differentiate between levels of competence, and which allows for a standardized, but more individualized assessment of competence than few other tools available.[108]
Bronchoscopy in ICU, anesthesiology and thoracic surgery		
Bronchoscopy in anesthesiology and ICU	N° of procedures that should be undertaken under supervision: Bronchoscopy via nasal and oral route and via tracheostomy 50/25 and ETT: 100/50[108] Nasotracheal FOI: 45[109] Difficult intubation: unknown Double lumen tube positioning: 22-38[110] Tracheostomy: 20/10 supervised Procedures[108, 111]	Multiple Choice Questions (MCQ) Case-Based Questionnaire Case-Based Discussion (CBD) Simulated assessment Direct observation of procedural skills (DOPS): predetermined checklist of a specific task on the use of flexible bronchoscopy in ICU (e.g. PDT-STAT, Percutaneous Dilatational Tracheostomy Skill and Task Assessment Tool)[32] Outcome assessment Percentage of complications from the Operative room register Ability to introduce the bronchoscope: >90% Measures of performance of a specific task on the use of flexible bronchoscopy in ICU (time to task completion, number of attempts)
Bronchoscopy in thoracic surgery	• For thoracic surgeons: the American Board of Thoracic Surgery (ABTS) requires resident- • trainees in the general thoracic surgery track to perform 40 bronchoscopic procedures: 30 simple • diagnostic procedures, including airway inspection, BAL, and endobronchial or trans-bronchial biopsy, and 10 therapeutic procedures.	• MCQ • Case-based questionnaires • DOPS for flexible and rigid bronchoscopy Outcome assessment: • See flexible and rigid bronchoscopy • Assessment of outcomes and complications • Infiltration of the margins of surgical pulmonary resection • % of "lung sparing" surgical procedures in comparison with preliminary evaluation
Bronchoscopy in lung transplantation	• 20% more than the number recommended for diagnostic and operative procedures	• MCQ • Case-based questionnaires • DOPS for flexible and rigid bronchoscopy **Outcome assessment:** • Assessment of outcomes and complications

(To be continued)

TABLE X.—*Quantitative and qualitative assessment of procedures in IP (continues).*

Procedure type	Quantitative assessment for achieving competence/maintenance	Qualitative assessment
Emergencies		
Emergency in IP	• Unknown	• MCQ • Case-based questionnaires • DOPS for flexible and rigid bronchoscopy
New treatments in asthma and COPD		
Endoscopic Lung Volume Reduction Treatment (ELVR)	• Unknown	• MCQ • Case-based questionnaires • DOPS Outcome assessment: • Assessment of outcomes (mortality, survival, complications, pulmonary function, quality of life, dyspnoea scores) in National and international registers (e.g. coils)
Thermoplasty	• Unknown	• MCQ • Case-based questionnaires • DOPS

Number of supervised procedures needed according to the different societies. The first number represents the minimum training required and the second (when present) the minimum procedures per year to maintain competency.
ERS: European Respiratory Society; ATS: American Thoracic Society; BTS: British Thoracic Society; TSANZ: The Thoracic Society of Australia and New Zealand; ACCP: American College of Chest Physicians; CCG: Consensus Conference Group of Master Program in Italy;
TBNA: transbronchial needle aspiration, EBUS: endobronchial ultrasound; ICU: intensive care unit.

Structured and/or certified courses in IP

With the aim of overcoming traditional teaching methods, different teaching models are available for IP:

• **short courses** useful for starting the Interventional Pulmonology or updating on specific topics (*i.e.* ERS courses [EBUS training program Part 1, Rigid bronchoscopy, Practical pleural skills, Pediatric bronchoscopy, Thoracic ultrasound, Interventional bronchoscopy, Thoracic Imaging, Live stream: Thoracic imaging, Thoracoscopy and pleural techniques], Boot Camp in Florence – Weeks In Interventional pulmonology in Ancona-Italy);

• **structured competence-oriented courses**, where a diploma is obtained:

• IP fellowships in the USA requires 12 months of dedicated training after completing residency in internal medicine and pulmonary/ critical care fellowship. This training spans a minimum of 7 years after medical school, equivalent to that of the neurosurgery training. Recently, there was a multi-society guideline on the minimum requirements of IP fellowship programs involving five different medical societies [American Association for Bronchology and Interventional Pulmonology (AABIP), Association of International Pulmonary Program Directors (AIPPD), American College of Chest Physicians (ACCP-Chest), American Thoracic Society (ATS), and Association of Pulmonary and Critical Care Medicine Program Directors (APCCMPD)]; [100]

• the ERS board certification for EBUS based on theory (knowledge), simulation training and supervised training on patient with a final assessment with videos and certification. The ERS working group on IP plans to extend this experience to other skills and procedures, such as thoracoscopy and Advanced Thoracic Ultra-Sound (TUS);

• Master Programs in Italy: for ten years at the Florence University there has been a 1-year University 2nd-level Masters course in Interventional Pulmonology during which the trainee is expected to collect 63 University credits (CFU) over a period of about 10 months: the aim of this Master is to provide a structured training in Interventional Pulmonology, dovetailing it to international standards.[27] This Master (http://master.pneumologia-interventistica.it) offers students the core knowledge and skills needed by the Pulmonologist in order to achieve the professional competence envisaged in this publication. As the numbers of procedures required to achieve competence is beyond the possibility of a single centre, a perfect integration and cooperation between Hospital and University Centres would allow the programme to train professional Interventional Pulmonologists in a more structured and effective manner. Certified Hospital Centers have the knowledge base, skills, attitudes, cases and series of patients; while University Centers have the teaching approach, the attitude to research, and the institutional task of certifying competence. Following the model of airline pilot training, every practitioner have his/her own Logbook (http://act.pneumologia-interventistica.it), the Interventional Pulmonologist's personal Flightbook, where he/she could record every individual procedure he/she has performed, every training course attended, including intermediate and final assessments of his/her competence, during initial stages, during Master's and during his/her professional career (Table X). In 2018 the Italian centre of Ancona organized a Master on IP.

- in the UK, they have a structured and detailed curriculum, with competency-based assessment and sign off, especially for Basic Bronchoscopy, Ultrasound and pleural based procedures. Each trainee has a logbook for 5 years, which needs to be reviewed and signed off, periodically, by their supervisors. Furthermore, in the Manchester region, an online based 'Pulmonary passport' has been introduced, which includes all procedures, EBUS, Thoracoscopy etc. UK also do not have a national training curriculum for IP. If pulmologists have interest in IP, they can apply for an additional 12 month fellowship in a few places such as Oxford, but no certificate is issued afterwards. In Oxford they have an official application process, open to foreigners as well, and often they have trainees from Australia or NZ;
- in Germany there is no structured training for IP available. Through the German Society of Pulmonology (Deutsche Gesellschaft für Pneumologie) basic and advanced bronchoscopy courses are offered, similar as the BTS do in the UK but this is not an equivalent to structured training. There is no fellowship programme as such available either. Usually, if a trainee is interested in IP, they will aim to work at a centres which is known for IP (such as the Thoraxklinik in Heidelbergh or Gauting 1 year every day) with simulator for the first few weeks and then hands on straight away. There is no certification for IP training in Germany either;
- in France a two-year Master is available, divided into 4 seminars. It includes 80 hours of theoretical courses divided into 4 mandatory seminars of 20 hours over 2 years. Each Seminar is composed of the following elements: teaching, provided by a group of university professors and professionals (8 hours); lessons made by local/regional professionals with experience in the subject (8 hours); practical laboratories (2 hours); written evaluation (2 hours). In addition, stages are available for the observation in clinical practice of advanced thoracic endoscopy techniques;
- the Bronchoscopy Education Project (www.bronchoscopy.org) provides training in fundamentals of flexible bronchoscopy. The goal is to build a common level of excellence across national borders. They use models, simulation, role-playing, case-based learning exercises, and objective measures of competence (using assessment tools and checklists) to improve technical skills, knowledge, and decision-making. Are available a collection of checklists and user instructions: Moderate sedation, Fluoroscopy, Informed consent, Patient safety, Practical Approach, Bronchoscopy step-by-step, Proctored bronchoscopy, IFB Program completion, Train the trainer courses.

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