Today's Treatment

Diseases of the respiratory system

Introduction: structure and function of the lungs

DUNCAN W EMPEY

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The prime function of the lungs is to bring air into close contact with blood so that oxygen may diffuse into and carbon dioxide out of the blood. In addition, the lungs have important non-respiratory functions such as clearing particles from the airways and converting or inactivating circulating polypeptides, prostaglandins, etc. The development and growth of the lungs are complex, and these and many other aspects of the normal lung have been extensively reviewed recently¹; I will therefore concentrate on the relations between structure and function in the adult lung.

General structure

The trachea branches into two main bronchi and these then subdivide into lobar bronchi, segmental bronchi, and so on for 27 generations. The first 19 make up the conducting airways, which have no gas-exchange function; the first seven of these generations are the cartilaginous airways or bronchi; and 8-19 are membranous airways or non-respiratory bronchioles that end as terminal bronchioles. Generations 20-23 consist of respiratory bronchioles and 24-27 are alveolar ducts; both of these have alveoli arising from them and participate in gas exchange. The branches arising from a single terminal bronchiole are collectively known as the terminal respiratory unit. The conducting airways receive their blood supply from the bronchial arteries, which arise from the aorta and its branches. Together the cartilaginous bronchi and the non-respiratory bronchioles make up the bulk of the anatomical dead space, so called because air within them does not take part in gas exchange.

The cartilaginous airways range from the trachea and larger bronchi to bronchi about 2 mm in diameter. They are supported by incomplete rings of cartilage, and smooth muscle is also present. The non-respiratory bronchioles range from 2 mm to 0.6 mm in diameter. They lack cartilage and secretory glands but do have smooth muscle in their walls. In the larger bronchi smooth-muscle contraction brings together tips of U-shaped cartilages, and in the medium- and smaller-sized bronchi and bronchioles, because of the distribution of the muscle fibres in their walls, contraction reduces both the calibre and the length of the airways; thus airway smooth-muscle contraction produces increased rigidity as well as narrowing of the airways.

Protective mechanisms

The larger airways are lined by ciliated, pseudostratified columnar epithelium, the thickness of which gradually decreases as the airways become smaller, so that the epithelium is only a single layer of almost cuboidal ciliated cells in the terminal bronchioles. The cilia have a co-ordinated beating action (more than 1000 beats/min) that sweeps the mucus lining of the airways from the periphery towards the trachea and pharynx. The nose filters most particles larger than 10 μ m from the inspired air, and the multi-branching structure of the conducting airways encourages particles with aerodynamic diameters between 2 and 10 μ m to impact or sedimentate on the airway surfaces. This serves to protect the alveoli from all but the very smallest particles. Particles that are trapped on the mucus lining of the airways are carried out of the healthy lung quite rapidly (less than 10 hours for 90% clearance), though there is wide individual variation in actual speeds of clearance; coughing helps the clearance of larger collections of mucus. In addition, soluble pollutants (such as sulphur dioxide) are removed by being dissolved in the fluid lining of the respiratory tract, and antibacterial substances and specific antibodies in the secretions play an important part in defending the lungs against damage.

The mucus layer is formed partly by the goblet cells, which are found throughout the conducting airways; but the bulk of the secretions are produced by the bronchial glands. These are characteristic of the larger bronchi and are situated in the submucosal layer and connected to the surface by ducts. Irritants may cause discharge of the contents of the bronchial glands by a reflex mediated through the parasympathetic nervous system. Chronic irritation by cigarette smoke and other pollutants may contribute to chronic bronchitis, in which the bronchial glands increase in their complexity and number of cells, and so produce more mucus.

Mast cells are found in the submucosa of the conducting airways; they resemble circulating basophilic leucocytes, but characteristic cytoplasmic granules can be shown by electron-microscopy. The exact chemical content of human mast cells has not been determined but animal studies suggest that they contain histamine, proteolytic enzymes, and many other pharmacologically active substances. These are discharged in response to antigen-antibody reactions on the surface of the cell and thus may lead to asthma.

Airway calibre and airflow resistance

As the bronchi and bronchioles branch within the lung, so their calibre decreases, but the total cross-sectional area of the airways increases with successive generations of airways. Thus the velocity of airflow is reduced as air passes into the periphery of the lung, and the bulk of the resistance to airflow is in the

Department of Medicine, The London Hospital (Whitechapel), London E1 1BB

DUNCAN W EMPEY, MB, MRCP, honorary lecturer and senior registrar

trachea and larger bronchi. As most simple lung function tests that attempt to detect changes in airway calibre are influenced by changes in airway resistance they reflect changes in calibre of the larger airways; the more peripheral airways (with a diameter of less than 2 mm) may be quite diseased and narrowed before any changes in airway resistance can be measured, and complex techniques are needed to show abnormal function in this "silent area" of the lung.

During inspiration the airways are distended, and during expiration their calibre is reduced. Airway narrowing may also be caused by mucosal swelling, mucus secretion, or contraction of the bronchial smooth muscle in response to chemical or nervous stimuli.

Innervation

The lung is innervated by branches of the vagus nerve and fibres from the upper four or five thoracic sympathetic ganglia. The airway smooth muscle is probably innervated by both parasympathetic and sympathetic fibres but physiological studies have shown that parasympathetic innervation predominates. The airway smooth muscle is, however, richly endowed with β -adrenergic receptors, which may respond to inhaled or circulating catecholamines causing smooth muscle relaxation.

Within the airway epithelium are unmyelinated nerve endings, which are probably rapidly adapting irritant receptors or "cough" receptors. These are mainly concentrated in the larger airways, and the afferent fibres travel in the vagus nerve; such stimuli as irritant gases, pulmonary emboli, and pulmonary congestion may act on these irritant receptors to produce cough, hyperventilation, and bronchoconstriction. The non-specific bronchial hyperreactivity that is so characteristic of asthma may be a manifestation of unduly sensitive irritant receptors, though the subject is controversial. Other receptors within the lung are pulmonary stretch receptors, which may affect breathing pattern in the newborn but are probably not active after the neonatal period; and J receptors, which may contribute to the sensation of dyspnoea accompanying such diseases as pulmonary embolism or oedema.

Pulmonary vessels

The pulmonary arteries branch with the airways as far as the respiratory bronchioles and supply blood to the capillary network of the terminal respiratory units. The larger arteries are elastic and the smallest ones are muscular; autonomic innervation is from the sympathetic system. The pulmonary veins are thin-walled vessels that drain into the left atrium and have no fixed relation to the airways. The exact role of the supernumerary pulmonary arteries (not accompanying airways) and their corresponding veins remains to be defined. Although the output of the right ventricle equals that of the left, pulmonary artery pressure is much lower than systemic blood pressure. Because the pulmonary circulation is a flow-through system there is nothing analogous to the dead space of the airways.

The close structural relationship of the pulmonary arteries and airways means that any condition that impairs ventilation (such as collapse caused by a tumour) may also impair the circulation to the relevant terminal respiratory units; this is advantageous because the optimal overall balance between ventilation and perfusion is maintained. Local autoregulation also maintains the efficiency of gas exchange when, for example, pulmonary arteries constrict in response to hypoxia in any region of the lung. Thus the ventilation and perfusion of the terminal respiratory units are matched quite closely. If alveoli that are not adequately perfused are ventilated the physiological dead space is increased (wasted ventilation), and if alveoli that are not adequately ventilated are perfused mixed venous blood returns to the left side of the heart and causes hypoxia (shunt effect).

The pulmonary circulation also has non-respiratory roles—

it filters blood to remove particles and emboli, and endothelial cells convert or break down such substances as angiotensin I and the prostaglandins.

Lymphatic vessels are found within the lung as the deep or parenchymatous lymphatic plexus, and on the surface as the pleural network. Most branches of the pleural network enter the lung, and lymph flows towards the hilum along the parenchymatous or interlobular channels. When enlarged in diseases such as pulmonary oedema or lymphangitis carcinomatosa the lymphatic vessels in the interlobular septa may appear on the chest radiograph as the familiar Kerley "B" lines.

Terminal respiratory units

Distal to each terminal bronchiole are the airways from which the alveoli arise—these consist of respiratory bronchioles, alveolar ducts, atria, and alveolar sacs, which together are known as the terminal respiratory unit; this has its blood supply from the pulmonary artery. The terminal respiratory unit is the site of gas exchange. The volume of gas within it is known as the alveolar volume and it is the ventilation of this region (alveolar ventilation) rather than the total pulmonary ventilation that determines the efficiency of carbon dioxide excretion.

Some 25 million alveoli are present at birth, which increase in size and number until there are more than 300 million in the healthy adult. The alveolar surface area is 80 m², 90% of which is covered with pulmonary capillaries; here the area of contact between the body and the external environment is 40 times greater than on the skin. The alveolar-capillary membrane is composed of the alveolar epithelium and its basement membrane, the capillary endothelium and its basement membrane, and the surfactant layer. Ninety-five per cent of the alveolar epithelial surface is made up of the type I cells (squamous pneumocytes) which have broad cytoplasmic extensions only 0.1–0.3 μ m thick. There are numerically more type II cells (granular pneumocytes) but they are cuboidal and occupy less than 5% of the alveolar surface. They have microvilli and contain lamellated inclusion bodies, which are believed to be associated with the production of surfactant. The capillary endothelium is formed by cytoplasmic extensions from endothelial cells. Both the alveolar epithelium and the capillary endothelium rest on separate basement membranes, but where the capillary bulges into the alveolus the two are fused; elsewhere the basement membranes are separated by an interstitial space containing elements of connective tissue. The capillaries meander in and out of the interstitial space, bulging into different alveoli as they go, forming a complex three-dimensional network.

Gas exchange takes place across the thin portion of the alveolar-capillary membrane where the basement membranes are fused. Diseases such as fibrosing alveolitis, which were previously thought to impair gas exchange by thickening this membrane ("alveolar-capillary block"), are now generally believed to create their major effects by destroying the balance between ventilation and perfusion. There is some evidence that the ultimate effects of airway obstruction on an individual patient may depend on the amount of collateral ventilation. The alveolar pores of Kohn, which allow gas to move between adjacent alveoli, and the canals of Lambert, which connect some respiratory and terminal bronchioles, are well recognised, though their functional importance—that is, how far they can compensate for airway obstruction—is not clear.

Lining the alveolar wall is a layer of surfactant, the principal component of which is dipalmitoyl lecithin. This lining film is crucial to normal respiration because it lowers the surface forces at the alveolar air-liquid interface, thereby reducing the work of breathing. As lung volume decreases, moreover, surfactant reduces the surface tension even further and ensures the stability of the alveoli and peripheral airways. Increased stiffness of the lungs and multiple areas of pulmonary collapse are characteristic of diseases such as neonatal respiratory distress syndrome, in which surfactant is reduced.

The alveoli are defended by alveolar macrophages. These

phagocytic cells ingest any bacteria and other particles that reach the terminal respiratory units. Because of its probable importance in preventing many pulmonary infections the alveolar macrophage is the subject of intensive research.

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Thus the lungs have a complex structure that is well suited to their role of gas exchange, and many important non-

respiratory functions are now being identified. Recent work on the structure of the normal lung is helping us to understand the way in which diseases produce their effects, and this should point to improved methods of prevention and treatment.

Reference

¹ Murray, J, *The Normal Lung*. London, Saunders, 1977.

Letter from . . . Dublin

Doctors to tradesmen

EOIN O'BRIEN

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After the electorate's unequivocal dismissal of the Coalition Government in June 1977, Mr Charles Haughey has succeeded Mr Brendan Corish as Minister for Health and Social Welfare. Mr Haughey, an experienced politician with a reputation for efficiency and achievement, is a striking contrast to his predecessor, whose preference for indecision rather than the wrong decision characterised his term of office. After quietly watching health from the opposition benches Mr Haughey has seized his portfolio with characteristic enthusiasm, and has made it clear to the medical profession, his civil servants, and the public that he intends to get things done. Let us direct our attention to two issues occupying much of the Minister's time at present—the long overdue contract for consultants and the building of a new hospital for Dublin city.

Consultant contract

Most consultants in Ireland are not subject to a formal contract, deriving their income from a salary calculated according to bed occupancy (the "pool" system), sessional payments, and private practice; these consultants have to make their own provision for sickness, holidays, study leave, and pension. A smaller number of consultants, employed in area health board hospitals, are salaried, with superannuation and sick leave provision, and most of these also derive some income from private practice.¹ During the past few years there has been much discussion between the Department of Health and the profession's representatives. The consultants have expressed a preference for a sessional basis of payment, with remuneration for extra duties, and the right to private practice. The negotiations now taking place in Eire and in Britain are complex and crucial for the future of medicine in both countries. As doctors vie with the politicians for what is essentially money in one guise or another, the interests of the unrepresented party—the patient—can easily be overlooked. Of particular concern is the principle of

continuity of patient care, which has been almost completely abolished within our hospitals, and could now be in jeopardy at consultant level.

By continuity of patient care I mean the right of a patient to be looked after by a doctor thoroughly familiar with his illness, and not merely a doctor from another firm who has not had the good sense to follow the example of his nursing colleagues—that is, the transfer of verbal and written reports on all patients at the change of shift. Doctors and administrators may argue against the concept of continuity of care, but will the patient? Since the substitution of cross-cover for continuity of care, the patient, whether acutely or chronically ill, may be cared for by his own doctors during normal working hours, but when 5 o'clock, the weekend, or a bank-holiday comes God knows who will be called to him in his greatest need.

Looking back a decade or so, one can remember—often vividly, but not in too much anger—the system whereby for an annual salary the intern, often the SHO and at times the registrar, by alternating duties with his partners provided continuity of care for his own patients. These were the days before the introduction of what was euphemistically called *extra-duty payment* in Britain but quite bluntly *overtime* in Ireland. Undoubtedly in those days the doctor was underpaid and overworked. At times, overwork probably resulted in bad decisions (I cannot remember whether the comparison was with airline pilots or lorry drivers), but long hours on duty did not always mean long hours of work—these were the days of the thriving hospital mess, and many were the entertaining hours spent in this establishment while "on duty."

More important, however, was the experience gained under this old system. Experience can be acquired only by exposure to ill patients, and illness cannot be organised to comply with the dictates of shift-work. If a junior hospital doctor in 1963 worked twice as long as his 1973 confrère must it not follow that the latter is less experienced? The question is one of degree in deciding at what stage reducing the hours on duty becomes crucial to the training of the junior hospital doctor. For the doctor overtime payment means fewer hours on duty and more leisure and study time (but the treatment of diabetic keto-acidosis cannot be gleaned from journals, or the surgery of perforation from the textbook)—and, of course, more money, at the sacrifice of experience. For the patient overtime has resulted in the virtual disappearance of continuity of care. The sacrifice has been considerable, and both the junior hospital doctors and their consultant colleagues have paid little heed to the conse-

The Charitable Infirmary, Dublin

EOIN O'BRIEN, FRCP, MRCP, consultant physician