Foreword to the First Edition

The field of bronchoscopy has been radically affected by the advent of the fiberoptic bronchoscope in 1966. As Drs. Oho and Amemiya show in this volume, the range of applications of the procedure is extremely wide. Fiberoptic bronchoscopy is particularly important for localization and diagnosis of cases which present with symptoms or have positive sputum cytology but which reveal no abnormalities on X-ray and also for the diagnosis of roentgenographically recognizable abnormal findings. However, in order to correctly evaluate pathologic findings, a thorough knowledge of the normal bronchus is essential, and to that end Drs. Oho and Amemiya have devoted a considerable amount of the book to describing and illustrating the normal bronchus. The range and depth of the book, combined with its clarity and brevity, render it valuable not only for endoscopists but also for chest physicians and chest surgeons.

In 1950 I received instruction in rigid bronchoscopy from Professor J. Ono of Keio University, the man who introduced the bronchoscope to Japan. At that time bronchoscopy was primarily performed as a preoperative examination technique in pulmonary tuberculosis cases, but from approximately 1952 lung cancer came to occupy an increasingly prominent position. In 1954 Dr. Oho joined the Department of Surgery of Tokyo Medical College and together we performed almost all the bronchoscopy procedures for the department. In 1966 the fiberoptic bronchoscope was developed and, in addition to his responsibilities as a thoracic surgeon, Dr. Oho took over complete responsibility for fiberoptic bronchoscopy in the department, as well as development of the instrument, accessories and techniques and he is now a highly respected authority in the field. In addition I have the greatest regard for the manner in which Dr. Oho supervised the compilation of records and materials which made this book possible. I would also like to express my respect and admiration for the efforts of Dr. Amemiya, one of the most capable members of my staff who has been of particular help in providing pathologic clarification of the background of clinical findings. Finally I would like to thank Mr. James Patrick Barron without whom this work would not have been published in English.

December, 1979

Yoshihiro Hayata, M.D.
Professor and Chairman
Department of Surgery,
Tokyo Medical College
Preface to the Second Edition

Four years have passed since the publication of the first English edition of this volume and over two years since the publication of the third Japanese edition. The response to both the English language and Japanese language versions has been greater than either of the authors dared to hope, and as a result this volume has enjoyed widespread use among clinicians. While this is a cause for rejoicing on the part of the authors, it also makes us deeply feel our responsibility.

The velocity of advances in medicine borders on the vertiginous. A significant difference in the diagnosis and treatment of respiratory tract diseases can be seen between 1980 and 1984. The field of fiberoptic bronchoscopy is no exception, with the development of instruments such as the BF-6C. New high quality instruments are making it able for us to recognize findings and phenomena of which we were previously unaware and comparison of the detailed appearance of the bronchial wall and the histological findings of resected specimens is contributing to deeper knowledge concerning evaluation of the endoscopic findings.

Also much clinical work has been performed at our and other institutions since 1980 on clinical applications of Nd-YAG laser beams transmitted through the fiberoptic bronchoscope. In this volume we present our evaluation of this technique, its indications and limitations.

In response to the above-mentioned advances in the field, most of the photographs in the first edition have been replaced in this edition by photographs taken with the BF-6C and we also have attempted to analyze findings using the most up-to-date, endoscopical, surgical and pathological knowledge.

While the authors are still not completely satisfied, we earnestly hope that this book will in some way contribute to the understanding of endoscopically observed pathological findings and thereby to the diagnosis and treatment of patients.

Lastly the authors would like to express their deepest gratitude to Professor Yoshihiro Hayata for his continual warm support. We also thank from our hearts James Patrick Barron, Associate Professor of St. Marianna University School of Medicine, who translated the first edition, for again spending much effort in translating this edition from Japanese.

January, 1984

Kenkichi Oho and Ryuta Amemiya
Preface to the First Edition

Bronchoscopic knowledge is essential for comprehension of diseases of the respiratory system. It is the conviction of both authors that in order to make a competent assessment of pathological findings the bronchoscopist must have a thorough knowledge of the appearance of the normal bronchus and of normal variations of the bronchial tree. One of the main purposes of this book is therefore to promote deeper basic understanding of bronchoscopic findings. Thus almost half of the color plates are devoted to normal findings and the explanations of the plates are based on the histologic and anatomical composition of each site.

The fiberoptic bronchoscope has made epochal contributions to bronchology, while the instrument itself, its accessories and their uses have also shown considerable development. The aim of this book is to serve as a practical introduction and manual for those who wish to practice fiberoptic bronchoscopy, presenting the appearance of the normal bronchus as well as pathological findings as they are viewed through the instrument, in addition to the various techniques and applications to which this versatile instrument can be put.

Acknowledgements:
All the material presented in this book was obtained from cases treated at the Department of Surgery of Tokyo Medical College, chaired by Professor Yoshihiro Hayata. Most of the photographs were taken by the authors, but we would like to thank Dr. Tadakiyo Hayashi, Dr. Ippei Ogawa and Dr. Naganobu Hayashi who photographed the others. The authors use only Olympus instruments, and all the photographs in this book were taken with the BF-B3, which is available to bronchoscopists throughout the world. The authors would especially like to thank Dr. Yukio Shimosato, Chief of the Pathology Division of the National Cancer Center, Tokyo for his constructive comments. The authors also wish to express their deep gratitude to all their colleagues in the Department of Surgery, Tokyo Medical College, in particular to Professor Yoshihiro Hayata for his kindness, advice and efforts to create an environment in which the clinical and research work necessary as a background to this book could flourish.

Finally we would especially like to extend our thanks to Mr. James Patrick Barron for his translation of the text and suggestions on this work. With
considerable experience in translating Japanese medical manuscripts into English, he was also responsible for creating the motto of the World Congress on Bronchology, Tokyo, 1978, "More Hope with the Bronchoscope"

December, 1979

Kenkichi Oho and Ryuta Amemiya
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Introduction

*Open Tube Bronchoscope or Flexible Fiberoptic Bronchoscope?*

Between 1975 and 1983 about 15,000 bronchoscopy procedures were carried out in the Department of Surgery of Tokyo Medical College. Not once was the rigid instrument employed in that eight-year period, nor was it ever felt that it should have been selected for any given procedure in favor of the fiberoptic bronchoscope. In our minds therefore, the rigid bronchoscope has been totally replaced by the fiberoptic bronchoscope. Of course, should any case present in which the rigid bronchoscope appeared advantageous either for the patient's or the physician's benefit, then we would recommend selecting that instrument without any hesitation. Various countries and institutions have varying customs and rules, in particular regarding anesthesia, and of course the endoscopic technique is an individual matter, thus one cannot make a blanket statement on the matter. Many colleagues occupying positions of authority concerning bronchoscopy in the West have adopted the standpoint that there are indications for both instruments, and that the instruments should be employed selectively on that basis. In particular, many profess that a foreign body in the bronchus is an indication for the rigid bronchoscope. However, although we cannot claim to have experienced an overwhelming number of foreign body removal cases, nevertheless we have performed all of them with the flexible fiberoptic instrument with 100% success. Most cases were children aged under two years of age, and these consisted of eight peanuts, three soy beans, two bullet shaped plastic ends of ball point pens, one cedar leaf fragment and one pin, and there were three cases of adults with a gold dental crown in the lower lobar bronchi. While this number in itself is rather small, a survey of the major institutions in Japan treating diseases of the chest showed that most of them employ the flexible instrument for foreign body removal, even in children. Recently numerous reports in Western literature have appeared on the subject of the removal of foreign bodies with this instrument, and it appears that the future will observe the spread of this technique. In response to this development, and as one cannot anticipate exactly what kind of foreign body one will have to deal with, an increased and more effective range of grasping forceps for use with a standard size channel instrument is required. Since children under the age of three or four are in general uncooperative, the procedure is performed under general anesthesia, but this, i.e. a very young child, is the only type of
procedure which we perform with general anesthesia.

Another commonly expressed indication for the rigid instrument is massive bleeding\(^{57}\). However we successfully use the fiberoptic bronchoscope without a tracheal tube in all cases, such as massive bleeding in lung cancer, spontaneous bronchial bleeding during puberty or menopause, bleeding due to bronchiectasis or biopsy of bronchial adenomas, and have never encountered a single fatality.

In experiments in which bronchial bleeding was induced in dogs, the authors recognized that amounts of bleeding exceeding the suction capability of the BF-1TR were also beyond the capacity of the conventional rigid bronchoscope. Also, even if a tracheal tube were inserted into the main bronchus of the non-bleeding side, blood flowed around the sides of the tube and was aspirated by that side, thus the use of a tracheal tube was found to be ineffectual. The only effective method with a tracheal tube was observed with a cuffed tracheal tube.

If bleeding is encountered, the most important point is to quickly ascertain the side (left or right) and place the patient lying on that side. Then, in order to prevent blood being inspired into the lung in which there is no bleeding, the tip of the fiberoptic bronchoscope is inserted to just inside the orifice of the main bronchus of the bleeding side and suction is performed. When the bleeding begins to abate, the tip is slowly advanced, sucking out coagula as one proceeds, searching for the site of the bleeding. Some bronchoscopists\(^{57,94}\) have expressed the view that in bleeding cases the distal tip lens of the fiberoptic bronchoscope becomes clouded, which they claim renders the rigid instrument preferable. However concerning this point we feel that the rigid and the flexible have the same problem, i.e. if the rigid bronchoscope is one with a light bulb at the tip, the light bulb will become clouded, and if a rigid fiberoptic bronchoscope is used, its distal lens will become clouded. In the case of massive bleeding it is essential to ensure that blood is not inspired into the healthy lung and to maintain a wide airway between the glottis and the healthy bronchus. From this consideration, a tracheal tube cannot be recommended on the grounds that it reduces the tracheal space. For an experienced bronchoscopist, to insert the fiberoptic bronchoscope from the mouth to the carina is the work of only a few seconds. Therefore, thinking of the convenience of inserting or removing the flexible instrument, the opinion that it should be used with a tracheal tube does not deserve consideration.

The opinion has been voiced that the flexible fiberoptic bronchoscope is not indicated in the treatment of small children as it may cause ventilation embarrassment\(^{44,57}\). Theoretically the use of the open tube rigid bronchoscope has been recommended in children up to the age of 2–3. This however does not permit detailed examination of the bronchial wall. Therefore, in order to accomplish detailed examinations, small diameter flexible fiberoptic bronoscopes such as the BF-4B2, BF-3C4, BF-3C3R are used.

Our policy is to perform the procedure with the flexible fiberoptic bronchoscope, even in patients aged less than three. Although a certain degree of finesse and dexterity is required, the approach consists of very rapid examination, repeated if necessary, with the patient under general anesthesia. The time required
for a single insertion and examination is 40–50 seconds, and should more time be required the fiberoptic bronchoscope is removed for reevaluation of oxygenation and anesthesia. From the age of ten, patients are generally cooperative and the procedure can be performed under local anesthesia in almost all cases. The question of instrument of choice is in fact only partly related to the physical and mechanical attributes of the two types of instrument, primarily it is a question of technique.

Some clinicians have expressed preference for the rigid bronchoscope on the basis that it provides larger and more easily evaluated biopsy specimens\textsuperscript{12,57}. We opt to use the fiberoptic bronchoscope even for biopsy of the trachea or main bronchus in order to minimize discomfort. Again, there have been a considerable number of reports detailing the resection of non-malignant tumors in the bronchus by means of a large-channel fiberoptic bronchoscope (BF-1TR)\textsuperscript{108}). The fiberoptic bronchoscope makes it possible to completely and safely remove non-malignant tumors or granulomas from any location in the bronchial tree as far as the 4th order bronchi. The therapeutic applications of the instrument are expanding, particularly with the development of electrosurgical and laser techniques.

Our experience, especially with the forceps with the holes in the cups which we developed, has shown that the fiberoptic bronchoscope provides specimens adequate for pathological diagnosis. Furthermore the fiberoptic bronchoscope also makes it possible to obtain specimens from almost any point in the lung by transbronchial lung biopsy (TBLB) for diagnosis of solitary lesions, and also renders feasible the performance of repeated surveys to ascertain therapeutic effects, which would be extremely difficult to attempt with the rigid instrument. We feel that in this concern the advantages and superiority of the flexible instrument over the rigid are clear.

The use of the fiberoptic bronchoscope through the rigid bronchoscope has been suggested\textsuperscript{104} particularly in the extraction of foreign bodies\textsuperscript{21} or in cases with positive sputum cytology and negative chest X-ray\textsuperscript{57}. Because of ventilation considerations this methodology is definitely inadvisable in young children, and certainly in sputum-positive, X-ray-negative cases the fiberoptic bronchoscope is clearly the instrument of choice to obtain cytology specimens from left and right bronchi, selective segmental irrigation and confirmation of the site of the tumor. Furthermore since the visual range of the fiberoptic instrument extends as far as all segmental bronchi, most of the latter type of cases can be confirmed by one procedure. By the adoption of such an unnecessary and clumsy methodology one simply negates to a large extent the advantage of the flexible instrument and causes the subject significantly greater discomfort.

However, concerning the opinion that measurement of bleeding time is necessary before any biopsy procedure\textsuperscript{43} we are in full agreement. Before all procedures we routinely measure bleeding time, coagulation time, prothrombin time, partial prothrombin time and platelet count. These are necessary, particularly in TBLB, because although this is in most cases a safe procedure, it is contraindicated in cases with coagulopathy.
At the Department of Surgery of Tokyo Medical College Hospital we now perform approximately 2,000 bronchoscopy procedures per annum, and in the past decade have never employed the rigid bronchoscope even once. Our experience demonstrates that the policy that the flexible fiberoptic bronchoscope and the rigid open tube bronchoscope have separate indications is not necessarily valid. We obtain fully satisfactory results with the flexible instrument inserted transorally without a tracheal tube and thus we are confident in asserting that the flexible instrument is superior in whatever situation the bronchoscopist faces. The ease with which the fiberoptic bronchoscope can be removed and reinserted totally negates any argument for the necessity of using a tracheal tube which reduces airway space. To move the flexible instrument from left to right or vice versa is a matter of seconds. To use the flexible instrument via a tracheal tube nullifies the functionality of the former and occasions the subject unnecessary pain.
In instrumentation and technique, the authors employ the BF-B3R (Fig. 1), an all-round fiberoptic bronchoscope with which all standard accessories can be used. The insertion shaft is satisfactorily flexible and possesses what is known as "torque free" characteristics, which means that the tip stays steadily at the angle to which it is adjusted without any tendency to straighten out. In daily use, we use it for a wide variety of procedures; routine observation and biopsy, bronchography, transbronchial brushing, transbronchial lung biopsy, transbronchial needle aspiration biopsy, bronchial toilet, intralobular injection of immunotherapeutic agents, and we even use one for our canine carcinogenesis experiments. The angle of the visual field is wide, which helps to expedite procedures, and the excellent resolution of the image which is provided by what
seems to be very compact and regular arrangement of fibers gives excellent observation and evaluation in addition to clearer photography. We have had experience with many other models of fiberoptic bronchoscopes but nevertheless we find that because of their optical characteristics, functionality and durability we rely almost totally on the BF-B3R and also, although to a lesser degree in terms of frequency, the BF-1TR. For photography the recently developed BF-6C is employed as it yields higher resolution and a brighter image. As it also has a 120° visual field it is convenient for rapid orientation.

The range of fiberoptic bronchoscopes is continually expanding, and it is therefore extremely difficult to make a meaningful comparison of the models presently available. To explain why we rely greatly on the Olympus BF-B3R, we would like to present our thoughts on the instrument in comparison with other excellent fiberoptic bronchoscopes of the same general class, the Machida FBS-6TII and FBS-6TLII. The tip of the BF-B3R (Fig. 2) can be turned 160° up and 130° down, thus providing a total angulation capability of 290° which is the largest of any bronchoscope of which we are aware. While the FBS-6TII has a maximum upward angulation of 180°, its downward angulation is only 60°. Also the Machida FBS-6TLII has angulation characteristics of 150° up and 60° down, thereby on occasion necessitating revolution of the instrument along its own axis which causes increased friction with the bronchial epithelium. Furthermore we find that the insertion tube (i.e. the portion between the control unit/eyepiece and the 4 cm angulation section at the tip) of the BF-B3R is more flexible, which again causes less resistance to the bronchial wall. Finally, we find that since the BF-B3R has been constructed with graded flexibility, with an extra flexible section at the tip, it is easy to handle, particularly in terms of insertion into both apical lobe bronchi. Of course this is a matter of personal preference and familiarity with the instrument, and the authors would like to stress to the prospective fiberoptic bronchoscope proprietor the need for a sober appraisal of the overall attributes and judgment of how it suits the operator.

Fig. 2 The tip of BF-B3R type fiberoptic bronchoscope with FB-19C forceps (Olympus).
Fiberoptic Bronchoscope Tips

All fiberoptic bronchoscopes are "frontal view" instruments, i.e. the lens is perpendicular to the longitudinal axis of the instrument, unlike some other types of fiberoptic endoscopes. A close-up view of various types of tips and their specifications are shown in Fig. 3.
Control Units

The BF-2TR has two channels, which means that while forceps or other accessory instruments are in place, additional anesthetic agents may be instilled or suction performed. This helps to maintain a clean lens and can facilitate a smooth procedure (Fig. 4 left). Figure 4 (right) shows the control unit of the BF-B3R, an all-round fiberoptic bronchoscope which we use with the greatest frequency. With the BF-B3R, observation and photography as well as cytologic brushing and histologic biopsy as far as subsegmental and some subsubsegmental bronchi can be carried out.

Fiberoptic Bronchoscope Accessories

Some accessories are only obtainable by direct order from the manufacturer, but we find that some of these are indispensable for daily clinical use. It is presumed that most of these will be available on a general commercial basis in the future.

Forceps and Handles

When selecting forceps etc., it must be borne in mind that an accessory designed for a bronchoscope with a wide instrumentation channel cannot be used with a standard fiberoptic bronchoscope. For daily clinical use we tend to rely mainly on the FB-19C, FB-21C and FB-15C for biopsy under bronchoscopic observation, the BC-10C and BC-11C for brushing, the BC-8C for cytologic diagnosis of peripheral lesions, and for transbronchial lung biopsy (TBLB) we generally employ the FB-19C, FB-21C, FB-20C and FB-15C. We have obtained good results by
developing forceps with holes in the cups to minimize tissue crushing which can hinder making a definitive histologic diagnosis. The needle in the joint of some forceps helps to prevent the forceps slipping and is of particular aid when the tissue is hard. Since one never knows when one may require them, a good range of forceps and brushes including grasping forceps for removal of foreign bodies should always be kept on hand. The handles of biopsy forceps, grasping forceps, cytology brushes and injection catheters vary, and the operator should familiarize himself with their use before attempting to use them (Fig. 5).

Light Sources

Although several light sources are available, for procedures performed in the fiberoptic bronchoscopy room, we find that we obtain brighter photographs with the large CLX-F. The smaller CLE-5 provides excellent visibility as do the CLV with its Xenon lamp, the CLS-F and the CLE-F which last also has an integrated flash system (Fig. 6). All of these are small and relatively light thus making them ideal for bedside or mass survey use. However we feel that the non-portable CLX-F, which also has a flash system, probably is the most suitable for any fixed facility for the procedure.

Cameras

Accurate recording of findings is of extreme importance. Many methods are available, including conventional still photography, Polaroid®, 16 mm cine and videotapes. Cine photography and videotapes possess great educational value, while still photography is most common in general clinical use.

These are the three types of camera which we use daily (Fig. 7). All three are manufactured by Olympus Optical Co., the SC-P under licence from Polaroid Corp. The SC16-3 is lightweight, has an automatic film winding mechanism and holds 16 mm cassette film. The OM-1 is a 35 mm camera body which is used with the SM-4S adapter (Fig. 8). The SC-P is also used in almost all cases and has the advantage of providing an instant record of pathological findings. Although the SC16-3 is extremely convenient in terms of size, weight and automatic film winding, the photographs it provides are small and can be difficult to read. Especially for presentations at scientific meetings or publications, enlarged duplicates are necessary and due to these considerations we generally employ the OM-1 + SM-4S for routine clinical use, in conjunction with the SC-P. Figure 9 shows the truncus intermedius of the same case as photographed by the three types of cameras.

Photographic recording of normal findings, particularly the bifurcations, is extremely important, and from the point of view of the angle of the visual field the BF-B3R is most suitable. However, for detailed analysis of the site of pathological findings the BF-6C is superior.
1. FB-19C open cup type biopsy forceps for use with standard-sized channel (2.0 mm).
2. FB-21C biopsy forceps (oblong with open cups) for use with standard-sized channel.
3. FB-24C biopsy forceps with spiked hinge. Other dimensions are identical to the FB-21C.
4. FB-15C alligator type biopsy forceps for use with standard-sized channel.
5. FB-20C open cup type biopsy forceps for use with wide channel (2.6 mm).
6. FB-18C biopsy forceps with spiked hinge for use with large channel.
7. FB-22C biopsy forceps with spiked hinge for use with large channel.
8. BC-10C standard cytology brush for use with standard-sized channel.
10. BC-9C cytology brush with sheath for use with wide channel.
11. BC-8C double-jointed cytology brush for use with standard-sized channel.
12. CC-3C double-jointed curette for use with standard-sized channel.
13. NM-3K injection catheter for use with standard-sized channel. Length of needle when projected from sheath: 4 mm, 23 gauge.
14. MN-18K injection catheter. The 23 gauge needle tip is 8 mm in length.
15. MN-22C injection catheter for use with standard-sized channel. The 18 gauge needle tip is 11 mm in length.
16. PW-1H** conventional type washing pipe for use with wide channel.
17. PW-5L spray type washing pipe for use with wide channel.
18. Electrosurgical cutter (flat type) for use with a large channel.
19. FD-1L** hot biopsy forceps for use with wide channel. For biopsy using cutting electric current.
20. KD-1L** needle type diathermic cutter for use with wide channel.

* Available by direct order from the manufacture.
** Not included in the standard instrumentation set.
21. FS-3L** surgical scissors for use with wide channel.
22. IE-1L magnetic extractor for use with wide channel.
23. FG-1D* long type grasping forceps for use with wide channel.
24. FG-2D* trident type grasping forceps for use with wide channel.
25. FG-3D* W-type (interlocking teeth type) grasping forceps for use with wide channel.
26. FG-16L basket type grasping forceps for use with wide channel.
27. FG-6L** alligator type grasping forceps for use with wide channel.
28. FG-10L, 11L* grasping forceps for use with wide channel. Teeth are shaped to allow them to bite into the foreign body.

29. FG-21L grasping forceps (rubber tips) for use with standard-sized channel.

30. Handle of biopsy forceps.

31. Handle of grasping forceps.

32. BC-9C handle of cytology brushes.

33. Injection catheter.

34. BC-9C disposable cytology brush before attachment.

35. Collection tube for selective segmental bronchial washing which can be used for cytological diagnosis in cases of inflammatory diseases, also can be used for bacteriological examination.
Fig. 6 Light sources.
Fig. 7 Cameras for fiberoptic bronchoscopy.

Fig. 8 Photography with the OM-1 and SM-4S.

Fig. 9 Photography with the BF-B3R and BF-6C. Findings of the same case taken with two different fiberoptic bronchoscopes and three types of cameras (truncus intermedius, squamous cell carcinoma, same case as shown in Figs. 96, 97.)
Cleaning and Sterilization

Cleaning and sterilization are extremely important. The methods we employ are described below, but of course other methods or agents could be acceptable. The recently developed Olympus OES series of endoscopes is completely waterproof and should significantly simplify cleaning and improve maintenance.

External Surface

The eyepiece and control unit should be wiped off with gauze dampened with alcohol, on no account must they be washed with liquids. The insertion tube and the distal tip should also be wiped off with dampened gauze, followed by washing with 2% glutaraldehyde solution and wiping off with gauze dampened with 70% alcohol.

For most fiberoptic bronchoscope procedures the same bronchoscope, cleansed and sterilized in the above manner, can be used for consecutive procedures. Exceptions to this are cases which have, or are suspected of having, tuberculosis, syphilis or hepatitis B-virus. Our policy is to sterilize the fiberoptic bronchoscope at least overnight after such a procedure, and therefore schedule them to be the last procedure in the day. Overnight sterilization is performed by formaldehyde gas or ultraviolet light sterilization in the fiberoptic bronchoscope cabinet. We employ ultraviolet light.

Biopsy Channel

The rubber cap at the proximal end is removed, the automatic suction valve inside is taken out, unscrewed and cleaned and sterilized. The channel is flushed with water and 2% glutaraldehyde solution, while the interior of the channel is flushed with a cleaning brush (Fig. 10). Next, after thorough cleaning with the brush, water is sucked up the tube, followed by 70% alcohol. Finally air is sucked through it to dry the channel.

Endoscope Washing Machine

The external surface and the internal channel of the fiberoptic bronchoscope can be washed simultaneously with an endoscope washing machine (Fig. 11). The washing machine washes with water and disinfectant, then dries the instrument. The entire process requires seven minutes.

Brushes, Curettes and Forceps

The manual control unit, shaft and tip of all brushes curettes and forceps are washed first with 2% glutaraldehyde solution, followed by water and finally with
70% alcohol solution. Particular attention must be paid to the material adhering to the tips of forceps or curettes, for in addition to the sanitary problem they pose, they can also prevent the instruments from functioning effectively. These instruments should also be kept overnight in the fiberoptic bronchoscope cabinet for sterilization by ultraviolet light or formaldehyde gas.

Storage and Sterilization

For storage in the bronchoscope cabinet all fiberoptic bronchoscopes and instruments should be placed hanging freely from their control sections. Overnight sterilization is performed in the cabinet, as described above, using formaldehyde gas or ultraviolet light.

Fig. 10  Channel cleaning brush,
(a) BW-7B for use with the BF-6C and BF-3C4
(b) BW-1B for use with the BF-4B2 and BFB3R
(c) BW-6B for use with the BF-2TR
(d) BW-2B for use with the BF-1TR

Fig. 11  The EW-D endoscope washing machine in the process of washing the BF-B3R.
Indications and Contraindications

Indications

Cases in which an abnormal shadow on chest X-ray appears to be located as far as the subsegmental or subsubsegmental bronchi are indications for fiberoptic bronchoscopy. However, the question of the indications or contraindications is also influenced by the degree of skill of the operator and the development of technique, thus it can be fairly estimated that the indications of the procedure will continue to broaden in the future. In terms of symptoms, bloody sputum or hemoptysis are strong indications for the procedure in order to elucidate the site of the bleeding. Other indications are persistent cough or a complaint of sputum. Yet another indication is a chest X-ray negative, sputum cytology positive case, where the procedure is used for visual examination and, if necessary, biopsy, brushing and selective washing in order to localize the site of the lesion. A foreign body in the bronchus is an indication for fiberoptic bronchoscopy, although some prefer to employ the rigid instrument. We feel the fiberoptic bronchoscope procedure is also indicated in high risk mass survey group cases who display moderate or severely atypical squamous cell metaplasia on sputum cytology.

Contraindications

The contraindications for the fiberoptic bronchoscope procedure are few, and can be considered to be roughly the same as has been accepted for the rigid bronchoscope. However, in this respect it is extremely difficult to make a generalized statement, as the crux of the matter is the technique and ability of the bronchoscopist.

Contraindications include general debilitation, cardiac cases \(^{23,99}\) in which the procedure might cause an attack or grave worsening of condition, and also cases with extremely poor pulmonary function.

For cases in which the PaO\(_2\) is below 50 torr under oxygen administration, the fiberscope should not be inserted for more than 15—20 seconds at a time, with a period of 30—60 seconds rest between insertions.

While some consider fiberoptic bronchoscopy contraindicated immediately after massive hemoptysis \(^{57,94}\), we do not believe that this is necessarily so. Our reasons are that we have experienced a considerable number of cases in which fiberoptic bronchoscopy was extremely valuable in establishing the site and condition of the bleeding, controlling the situation, and also in management thereafter. It is our considered opinion that in such cases fiberoptic bronchoscopy is indicated if an experienced operator is at hand. In our department our first step after hemoptysis is fiberoptic bronchoscopy, regardless of whether the amount be large or small, in order to determine the next step in the management of the patient.
The Fiberoptic Bronchoscopy Procedure

Premedication and Anesthesia

With the advent of fiberoptic endoscopy, bronchoscopy ceased to be a procedure occasioning the subject great discomfort. While the procedure can be performed under either general or local anesthesia, only the latter is employed recently in most adult cases at many institutions throughout the world. While some institutions still employ general anesthesia for the procedure, this should be attributed to the particular situation of such institutions and/or the social environment in which they are situated, rather than to any inherent need for the procedure to be performed under general anesthesia. The policy in operation at the authors' institution is that fiberoptic bronchoscopy can be performed by a properly trained operator even in cases in extremely poor condition, elderly cases over 75 years of age or at the bedside of cases which cannot be moved. If one adopts an attitude that the procedure must be performed under general anesthesia or in conjunction with the rigid bronchoscope then the very versatility and functionality for which the instrument has justly earned its reputation will be seriously restricted. As the procedure occasions the subject only a very slight degree of discomfort, we feel that there is no need for general anesthesia except in special cases, such as young children.

Premedication Between 15 and 30 minutes prior to the procedure 0.5 mg atropin sulfate is injected subcutaneously in order to reduce secretions and to prevent the vagovagal reflex. In cases when an especially strong reaction to the instrument is experienced, such as in highly strung cases, 35—70 mg Meperidine and/or 25—50 mg hydroxyzine hydrochloride (Atarax-P) is also administered.

Anesthesia The most common local anesthetic agents are lidocaine, cocaine and tetracaine. We use 4% Xylocaine (lidocaine), sprayed with the instrument depicted in Fig. 12. Xylocaine is probably the most popular of the three above mentioned agents, having lower toxicity than the other two, but its effects last for only about 30 minutes. One must also be careful not to administer more than 400 mg (i.e. 10 ml 4% solution)\(^{29}\). Cocaine has a longer period of effectiveness than lidocaine and may indeed be the best local anesthetic but dosage should be restricted to about 200 mg. Thus in cases in which lidocaine effectiveness diminishes, further administration of a small dose of cocaine would probably be the best method.

The administration of local anesthesia is generally performed with the subject in a sitting position. The oral lumen and pharynx are sprayed, then the operator pulls out the tongue as shown in Fig. 13. The elongated nozzle of the spray is gradually inserted and puffs of anesthetic are sprayed over the vocal cords and trachea at the beginning of each inspiration. Figure 13 shows the spraying procedure with the tip of the nozzle beyond the vocal cords at the tracheal
Fig. 12 Jackson type spray. The oral cavity, pharynx, larynx, glottis, trachea and bronchi are anesthetized by 4% Xylocaine or its equivalent, spraying in time with inhalation.

Fig. 13 Spraying procedure. The tongue of the subject is pulled gently and anesthetic is sprayed in time with his inhalation. In this photograph the tip of the spray is inserted as far as the vocal cords.
orifice. It is important to have the subject relax the neck and shoulders and to jut his chin forward. Care must also be taken to avoid unnecessary friction with the spray nozzle. By ensuring that spraying is done at the beginning of each inspiration once the vicinity of the vocal cords has been reached, one can obtain satisfactory anesthesia with a minimum of anesthetic. Should the subject evince a cough reflex during the procedure, small amounts of anesthetic (1.0—1.5 ml) may be instilled via the instrumentation channel of the instrument.

Insertion of the Fiberoptic Bronchoscope

Prior to discussing the actual insertion of the instrument, a point which must be stressed is the importance of first checking all instruments and equipment in order that the procedure may be performed as smoothly as possible. Generally if the operator is right-handed the control unit with the eyepiece lens is held with the left, to leave the right free for inserting forceps etc. However, the instrument can be easily manipulated with either hand. The angulation lever which controls the angle of the tip is operated by the thumb while the index finger is used to occlude the suction port. It is therefore necessary to keep the power source on the left of the operator to prevent the light guide and suction tubes crossing over in front of him. The subject, to whom the procedure should already have been fully explained, is requested to lie in a straight supine position on the examination table. After instructing the subject to relax and let the strength out of his shoulders he is told to jut out his chin and stick out his tongue, this last for the purpose of expanding the laryngeal lumen. A plastic mouthpiece which functions to protect the delicate instrument from an inadvertent bite is threaded up the insertion tube and held next to the control unit with the left hand as the tip of the instrument is inserted past the tongue along the midline of the body with the angle of the tip maintained slightly upward as far as the epiglottis (Fig. 14). Upon reaching the epiglottis the tip is returned to a neutral, i.e. straight, position and advanced, whereupon the vocal cords come into view (Fig. 15). Then the bronchoscope is advanced keeping the vocal cords in the center of the field of vision, and passage of the vocal cords is made, timing the insertion of the instrument with inspiration. Thereafter the tip is adjusted to a slightly downward angle until the trachea, when a neutral position is resumed (Fig. 16). Then the mouthpiece, which has been held next to the control unit, is slid down and placed in position between the subject's front teeth (Fig. 17). This is the transoral method without a tracheal tube which we use daily for routine procedures. We believe that this method gives the subject least discomfort and is also the easiest from the point of view of the operator. In addition this method permits observation of the pharynx, larynx, vocal cords and trachea, so that pathological changes in these locations can be detected.
Fig. 14 Epiglottis and pharynx. Advancing the fiberoptic bronchoscope beyond the tongue it enters the pharynx. Positioning it along the longitudinal axis of the body, the epiglottis comes in view. On occasion the epiglottis is attached to the posterior wall of the pharynx and it is difficult to view the larynx.

Fig. 15 Vocal cords. Advancing the bronchoscope beyond the epiglottis, the milky-white vocal cords come into view and the glottis can be observed opening and closing. The left and right cuneiform tubercles and the corniculate tubercles, which make up the aryepiglottic folds, can also be seen.
Fig. 16 From the vocal cords to the trachea. As the fiberoptic bronchoscope approaches the vocal cords, the intraglottic cavity and the anterior wall of the trachea can be seen. Angling the tip down, it enters the trachea.

Fig. 17 Fiberoptic bronchoscopy via direct transoral insertion without a tracheal tube. Here the mouthpiece has just been slid down from the control unit and inserted in the subject's mouth.
Methods of insertion naturally can vary according to institution and operator. These include transnasal insertion or insertion through a tracheal tube or rigid bronchoscope. Some operators prefer to perform the procedure after intubation with a tracheal tube or rigid bronchoscope to maintain the airway because of the possibility of respiratory complications, but in another section we have already discussed why we do not suggest these methods.

Some investigators have expressed the opinion that in cases of massive bleeding a tracheal tube should be inserted into the unaffected lung in order to maintain the airway, but unless a cuffed tube is used blood will be aspirated by the healthy side. Also, in terms of management of cases with IPPB and PEEP after such an incident, these steps will be ineffective unless a cuffed tracheal tube is used. It is therefore clear that as long as a cuffed tracheal tube is kept in the endoscopy room, the fiberoptic bronchoscopist will be able to ensure more effective management of bleeding cases than could be obtained by advancement of a rigid instrument or a tracheal tube without a cuff into the main bronchus of the non-bleeding lung.

Choice of method is a matter of personal preference but we feel strongly that transoral insertion under local anesthesia is the easiest and least trying for both subject and operator. We might add we have had no serious complications in over 15,000 procedures of fiberoptic bronchoscopy. Thus we feel the operator should select the simplest method which will achieve its objective and should try to reduce discomfort afforded the subject as much as possible.

Many clinicians have expressed a preference for transnasal insertion, but in the authors' experience, patients who have undergone both methods of insertion generally express a preference for transoral insertion. It may be possible that the smaller nasal lumen of Japanese may be one reason for this.

Figures 18, 19 and 20 depict the authors' method of tracheal tube insertion using the fiberoptic bronchoscope as a guide. This method is also employed when difficulty in intubating is experienced in surgical procedures performed under general anesthesia.

In general, when performing the bronchial toilet procedure postoperatively, transnasal insertion is easier than transoral insertion. If insertion is to be made through a tracheal tube, the outer surface of the fibrescope should be sprayed with silicon spray so that it can be passed more smoothly.

For removal of foreign bodies in pediatric cases the authors also employ the fiberoptic bronchoscope. In cases under the age of 5–6 the children are unable to comprehend the necessity of the procedure, and as a result do not cooperate. In such cases the procedure is performed under general anesthesia which is administered through a mask or by intubation. After sufficient anesthesia, the mask or tube is quickly removed and the fiberoptic bronchoscope is immediately inserted and the foreign body removed. In Japan the greatest number of foreign body cases are aged around one year old, at which age the BF-B3R is usually just able to be inserted into the main bronchus, therefore if a BF-4B2 is available, this would be more practical.
Fig. 18 First the fiberoptic bronchoscope is threaded through the tracheal tube, then the fiberoptic bronchoscope is inserted transorally as far as the trachea.

Fig. 19 Then the tracheal tube is moved smoothly down the fiberoptic bronchoscope.

Fig. 20 After the tracheal tube has been inserted as far as desirable the fiberoptic bronchoscope is removed.
However, it is important that the maximum insertion time possible in a case without natural respiration be less than 50 seconds. If removal of the foreign body is not achieved within that time the instrument should be removed and oxygenation and anesthesia administered again, the patient's position is changed if necessary and the most suitable accessory instrumentation is prepared for a second procedure. However if the child is old enough to understand, e.g., over the age of 7–8, and is given a thorough explanation of the procedure and of the alternative of surgery, usually it is possible to perform the procedure safely under local anesthesia.

Recently Nd-YAG laser treatment has been shown to obtain dramatic effects in a short period in certain cases and as a result has become increasingly widespread. Most of the cases of tracheal stenosis in which this method is indicated are emergency cases with severely compromised respiration. In such cases it is impossible to perform treatment with the fiberoptic bronchoscope inserted through a tracheal tube, and to perform it under general anesthesia would cause unwarranted danger.

The authors generally perform this type of treatment in a manner similar to conventional fiberoptic bronchoscopy under local anesthesia. The patient is placed in a supine position and the fiberoptic bronchoscope is inserted transorally, after which the laser transmission fiber is inserted through the instrumentation channel. However in cases of severe respiratory distress, the level of consciousness of the patient is temporarily lowered by administration of either 15–30 mg pentazocine or 10 mg diazepam.
Anatomy of the Bronchus

Bronchial Nomenclature

For any physician involved with the diagnosis of respiratory diseases a thorough knowledge of the anatomy and branching of the normal bronchus is not only extremely fundamental and important but is also necessary to fully comprehend endoscopic findings. Consequently, prior to performing a fiberoptic bronchoscope procedure a firm grasp of bronchial anatomy, branching, nomenclature and normal endobronchial findings is indispensable and can greatly influence individual progress.

Perhaps the most classical work on the branching of the bronchus is contained in Aeby's comparative anatomical research of 1880. Further achievements were made by Ewart (1889), Hasse (1892), Narath (1901), Felix (1920), Melnikoff (1924), Loeschcke (1924), Steinert (1926), Kramer (1932), Lucien (1936), Neil (1937), Huizinga (1938), Adams and Davenport (1942), Foster-Carter (1942) and many others. In 1943 Jackson and Huber published their results and were followed two years later by Boyden's studies of variations of the pulmonary segments. Their work forms the basis for the present nomenclature of the bronchus, and they were followed by Scannel (1947, 1949), Berg (1947) and Shinoi (1948).

Worldwide uniformity in describing bronchi, e.g. number, direction and distribution, is essential for further progress in this field. Table 1, and Figs. 21 and 22 show the nomenclature systems most commonly employed internationally. Table 1 shows the Latin nomenclature system, but for segmental bronchi, the bronchial numbering such as B1+2, B3 etc., which is commonly employed today is more appropriate. However, the bronchial tree shows highly individualistic features and many variations can be seen. Thus bronchography can help to determine the exact segment in which a certain bronchus bifurcates. In particular the high frequency of variations in the left upper division bronchus and the right upper lobe bronchus requires extreme care when deciding the name of any given bronchus bifurcating from them.
Fig. 21 Nomenclature for segmental bronchi.
<table>
<thead>
<tr>
<th>Segmental Bronchi</th>
<th>Right</th>
<th>Left</th>
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<tbody>
<tr>
<td><strong>Upper Lobe</strong></td>
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<tr>
<td>$B^1$: R. apicalis</td>
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<tr>
<td></td>
<td>a. Rm. apicalis proprius</td>
<td>a. Rm. apicalis</td>
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<td></td>
<td>b. Rm. subapicalis</td>
<td>b. Rm. subapicalis</td>
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<td>$B^2$: R. lobi superioris dorsalis</td>
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<tr>
<td></td>
<td>a. Rm. subapicalis dorsalis</td>
<td>a. Rm. lobi superioris dorsalis</td>
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<td></td>
<td>b. Rm. lobi superioris horizontalis</td>
<td>b. Rm. lobi superioris horizontalis</td>
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<tr>
<td>$B^3$: R. lobi superioris ventralis</td>
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<tr>
<td></td>
<td>a. Rm. lobi superioris ventralis lateralis</td>
<td>a. Rm. lobi superioris ventralis</td>
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<td></td>
<td>b. Rm. lobi superioris ventralis medialis</td>
<td>b. Rm. lobi superioris ventralis medialis</td>
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<td><strong>Middle Lobe</strong></td>
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<td>$B^4$: R. medius lateralis</td>
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<td></td>
<td>a. Rm. medius lateralis</td>
<td>a. Rm. medius lateralis</td>
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<td></td>
<td>b. Rm. medius medialis</td>
<td>b. Rm. medius medialis</td>
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<td>$B^5$: R. medius medialis</td>
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<td></td>
<td>a. Rm. superior</td>
<td>a. Rm. superior</td>
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<td></td>
<td>b. Rm. inferior</td>
<td>b. Rm. inferior</td>
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<tr>
<td>$B^6$: R. lobi inferioris superior</td>
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<td></td>
<td>a. Rm. superior</td>
<td>a. Rm. superior</td>
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<tr>
<td></td>
<td>b. Rm. lateralis</td>
<td>b. Rm. lateralis</td>
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<tr>
<td></td>
<td>c. Rm. medialis</td>
<td>c. Rm. medialis</td>
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<tr>
<td>$B^*$: R. lobi inferioris subsuperior</td>
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<tr>
<td></td>
<td>a. Rm. ventralis</td>
<td>a. Rm. ventralis</td>
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<td></td>
<td>b. Rm. dorsalis</td>
<td>b. Rm. dorsalis</td>
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<td><strong>Lower Lobe</strong></td>
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<td>$B^7$: R. mediobasalis</td>
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<td>a. Rm. lateralis</td>
<td>a. Rm. lateralis</td>
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<td>b. Rm. dorsalis</td>
<td>b. Rm. dorsalis</td>
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<tr>
<td>$B^8$: R. ventrobasalis</td>
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<td></td>
<td>a. Rm. lateralis</td>
<td>a. Rm. lateralis</td>
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<td></td>
<td>b. Rm. basalis</td>
<td>b. Rm. basalis</td>
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<tr>
<td>$B^9$: R. laterobasalis</td>
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<td></td>
<td>a. Rm. lateralis</td>
<td>a. Rm. lateralis</td>
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<td></td>
<td>b. Rm. basalis</td>
<td>b. Rm. basalis</td>
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<tr>
<td>$B^{10}$: R. dorsobasalis</td>
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<td></td>
<td>a. Rm. dorsalis</td>
<td>a. Rm. dorsalis</td>
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<td></td>
<td>b. Rm. lateralis</td>
<td>b. Rm. lateralis</td>
</tr>
<tr>
<td></td>
<td>c. Rm. medialis</td>
<td>c. Rm. medialis</td>
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Fig. 22 Bronchial nomenclature proposed by the late Prof. Kingo Shinoi, the former teacher of the authors, and adopted by the Japanese Committee on Bronchial Nomenclature in 1950.
Subsegmental Bronchi

As regards nomenclature of 4th or 5th order bronchi, the subscripts i, ii and α, β respectively are added to the respective a or b classification. Therefore, the most distal posterior or upper bronchus is designated as i or α and the more anterior, proximal or lower bronchus is designated as ii or β (Fig. 23). Figures 24–27 illustrate the subsegmental bronchi of the same case with normal lungs.

Fig. 23 Proposal made by the Bronchial Nomenclature Committee (Chairman: Yoshihiro Hayata, M.D.) to the 1970 annual meeting of the Japan Lung Cancer Society.
Figs. 24—27 Bronchoscopic pictures illustrating the nomenclature for peripheral bronchi of the normal upper lobes of the left lung.

Fig. 24  2nd and 3rd order bronchi of the left upper lobe.

Fig. 25  3rd, 4th and 5th order bronchi of the left upper lobe.
Fig. 26  2nd and 3rd order bronchi of the left upper lobe.

Fig. 27  3rd and 4th order bronchi of the left upper lobe.
Gross Anatomy of the Bronchus

The bronchus can be divided into two large categories — the extrapulmonary bronchus and the intrapulmonary bronchus. The completely extrapulmonary bronchi, which structurally resemble the trachea, consist of the left and right main bronchi and the truncus intermedius. While the left and right upper and lower lobe bronchi do somewhat resemble the trachea, their compositions alter prior to the bifurcation of the segmental bronchi, at the point where the extrapulmonary bronchi become intrapulmonary. The right middle lobe bronchus, although extrapulmonary in location, is intrapulmonary in terms of structure.

Extrapulmonary Bronchus

The trachea, left and right main bronchi and truncus intermedius have horseshoe-shaped cartilage crescents, varying in number according to the individual, generally 16—20 in the trachea, 9—12 in the left main bronchus, 6—8 in the right main bronchus and 4—6 in the truncus intermedius.

In the trachea the cartilage crescents extend around 2/3—4/5 of the circumference, as opposed to 1/2—2/3 in the main bronchus. The posterior wall of the bronchus, which is free of cartilage crescents and is referred to as the membranous portion, has a large amount of smooth muscle.

The composition of the trachea and these bronchi is as shown in Fig. 28. The elastic fiber, which extends around the entire circumference, reaches thicknesses of 8 μ in the membranous portion forming longitudinal folds.

Intrapulmonary Bronchus

The main difference from the extrapulmonary bronchus is the disappearance of the cartilage crescents. As is shown in Fig. 29, the crescents diminish to intermittent plates of cartilage at the point of transition (i.e. in the left and right upper and lower lobe bronchi) from the extrapulmonary bronchus to the intrapulmonary bronchus. Furthermore the layer of elastic fiber between the mucosal epithelium and the submucosa is gradually replaced by smooth muscle which extends in rings surrounding the entire circumference of the bronchus. Part of the elastic fiber remains consolidated into bundles at intervals between the mucosal epithelium and the smooth muscle all around the bronchus, almost as soon as the smooth muscle comes to extend around the entire circumference. Grossly these elastic fiber bundles appear as ridges running in a longitudinal direction. Therefore the crescent-shaped folds in the main bronchi and truncus intermedius are due to cartilage rings, while in the intrapulmonary bronchus the fine circular folds are formed by thin rings of smooth muscle. The composition of the intrapulmonary bronchus is as shown in Fig. 29.
Fig. 28a  Cross-section of the trachea and extrapulmonary bronchus.

Fig. 29a  Cross-section of intrapulmonary bronchus.

Fig. 28b  Cross-section of the right main bronchus.
1. Elastic fiber layer  2. Smooth muscle

Fig. 29b  Cross-section of right B8.
1. Elastic fiber bundles  2. Smooth muscle
Figure 30 shows the left main bronchus to the left upper lobe bronchus, upper division bronchus, lower division bronchus (lingular bronchus), $B^{1+2}$, $B^3$, $B^4$ and $B^5$. All the longitudinal folds of the membranous portion of the main bronchus continue to the lower lobe bronchus. Circular folds composed of smooth muscle begin immediately distal to the bifurcation of the upper and lower division (lingular) bronchi and continue to the periphery. They are most prominent in the lower wall. Longitudinal folds commence immediately prior to the orifice of the lower division (lingular) bronchus. The longitudinal folds, composed of elastic bundles, are inside the rings of smooth muscle. The circular folds are most remarkable in the lower wall of the upper lobe bronchus. In the upper division bronchus the longitudinal mucosal folds become increasingly noticeable from the bifurcation with the lower division (lingular) bronchus. In the peripheral bronchi the longitudinal folds become thinner and reappear beyond each bifurcation. It can be difficult to examine the superior wall of the upper lobe bronchus. In general it has a bright glossy luster.

Fig. 30 Left upper lobe bronchus of a 58 year-old male, autopsy specimen.
Figure 31 shows the left main bronchus and segmental bronchi of the pulmonary basal segment. Again in the lower lobe bronchus, longitudinal mucosal folds appear after the bifurcation of the upper and lower lobe bronchi. The mucosal folds are observed most clearly from the left lower lobe to the various segmental bronchi, and in this portion the depression between folds is quite deep because the elastic fiber bundles are thick. The pattern of the longitudinal folds is generally regular but occasionally merging or branching of folds can be seen. At bifurcations the folds become narrower, separate and continue, and new folds appear immediately after the bifurcation. In contrast to the whitish longitudinal folds, the intervening depressions have a yellowish tinge, and in them the orifices of bronchial glands can be seen as small dots.
Figure 32 illustrates left B⁶ with the bifurcations of B⁶a, B⁶b and B⁶c. As can be noted in the figure, two or three of the longitudinal folds of the main bronchus run into B⁶. In the lower lobe bronchus, longitudinal mucosal folds appear around the entire surface of the bronchus. The same kind of longitudinal folds can be observed in B⁶. The longitudinal folds can be observed as far as B⁶c, but in general the folds are most prominent from the main bronchus up to segmental bronchi, and from subsegmental bronchi on, they become harder to discern. The same kind of findings are seen in right B⁶.
In Fig. 33 some folds can be seen to continue from the right main bronchus to the right upper lobe bronchus and to B². Other folds, which appear after the upper lobe bronchus bifurcates from the main bronchus, continue to the segmental and subsegmental bronchi. Even within the same bronchus, those folds which originate more centrally are always thicker than those which appear later.

Figure 34 shows the findings from the right main bronchus to the segmental bronchi of the lower lobe upon incision of the mediastinal side. Again, some folds from the main bronchus can be seen to continue to the upper lobe bronchus and to the truncus intermedius. The anterior and left and right lateral walls of the truncus intermedius are relatively glossy, and the small points running in the direction of the longitudinal axis of the airway are bronchial glands. In the membranous portion 4–5 substantial longitudinal folds are present, and from the level at which the middle lobe bronchus branches off, longitudinal folds can be seen to gradually appear along the mediastinal side, and these continue to B⁶, the basal bronchus and B⁷. After the bifurcation of B⁶ mucosal folds are seen around the entire surface of the lumen and extend to all the segmental and subsegmental bronchi. The mucosal folds are most conspicuous in the basal bronchi of both lungs. Although in this figure only the orifice of the middle lobe bronchus can be seen, it resembles the left lower division (lingular) bronchus, and occasionally the circular folds caused by the smooth muscle can be remarkable.

![Fig. 33 Right upper lobe bronchus.](image-url)
Structural Factors of the Bronchial Mucosa and Factors Affected by Sex and Age

When performing fiberoptic bronchoscopy, the illuminating light penetrates the bronchial mucosal epithelium to a depth of about 0.5 mm, i.e. as far as the lamina propria. On occasion the spiraling circular smooth muscle can be recognized by a yellowish color but usually it is recognized by the undulating surface.

Usually the lamina propria and the whitish elastic fiber bundles, red vessels and anthracotic pigmentation contained in the lamina propria can be seen through the mucosal epithelium and basement membrane. Pathological conditions below the mucosal epithelium can often be indicated by the blood vessel findings (see p. 83). Therefore, when pathological changes exist in the lamina propria, it is only natural that surface irregularity and also changes in color can be recognized.
Generally changes in the smooth muscle or deeper, i.e. bronchial gland, cartilage and extramural tissue, can be recognized only as mucosal surface irregularities.

The mucosal lamina propria can change easily and rapidly in response to acute inflammation or stimulation by cough reflex, showing edema, hyperemia and infiltration of inflammatory cells. More than 50% of the bronchial artery distributes to the extramuscular layer (Fig. 35) and its vascular network cannot be seen in the normal trachea and bronchial mucosa.

The bronchial mucosal appearance varies with age and sex and also with the individual (Figs. 36—39). In young persons the longitudinal folds are generally clearly seen in the segmental and subsegmental bronchi but due to decrease of elastic fibers with advancing age\textsuperscript{106}, these are less clearly seen in older cases. Also due to atrophy of the smooth muscle and structural components of the lamina propria, increased prominence of the yellow white cartilage can be observed. Changes related to the menstrual cycle can also be recognized and in young women, the watery edematous appearance that is seen during menstruation is thought to be the result of an increase in goblet cells in the mucosal epithelium\textsuperscript{20,65}, and large chromatin granules in the eccentrically located nuclei of ciliated columnar epithelial cells.

When normal bronchial mucosal epithelial cells are present, the appearance is semi-transparent, but the presence of squamous cell metaplasia or intraepithelial invasion of squamous cell carcinoma causes alteration of the refractive index with the result that the appearance is opaquely white.
Fig. 36  Segmental bronchial mucosa (right $B^9$, $B^{10}$). The white longitudinal folds consisting of elastic fiber bundles and more distal circular folds composed of smooth muscle can be observed.

Fig. 37  (a) The blunt bifurcation of $B^{1+2}$ and $B^3$. In normal cases blunt bifurcations are composed of cartilage components.

(b) The sharp bifurcation of $B^{1+2}$ and $B^3$. So-called sharp bifurcations are composed of elastic fiber components, and all the subsegmental bifurcations seen here are of the sharp type.
Fig. 38  Right upper lobe bronchus of an elderly patient. In this 88 year-old male patient the longitudinal and circular folds have disappeared due to remarkable atrophy of the lamina propria and smooth muscle. Since only the cartilage tissue is relatively completely intact it appears prominently.

Fig. 39  Appearance of the upper and lower lobe bronchi of a young female. In a 21 year-old female the entire mucosal surface appears reddish and occasional longitudinal folds are seen. These findings are due to the thickness of the lamina propria which has enveloped the elastic fiber bundles.
Types of Branching and Their Frequency

Much research on the study of the bronchial nomenclature has been based on anatomical and bronchographic studies. As has been described above, the bronchi are numbered according to the pulmonary segment to which they distribute, e.g. the bronchus distributing to S1 is known as B1. Before the advent of the fiberoptic bronchoscope, naming of the bronchial tree in individual clinical cases was performed largely on the basis of the bronchographic findings. Formerly it was also necessary to refer to the bronchographic findings for correct endoscopic orientation and nomenclature. However today the bronchoscopic procedure has become simple and widespread and the nomenclature shown in Fig. 21 effectively prevents individual differences in the naming of bronchi, to the extent that in clinical terms there is now no problem in naming the bronchial tree on the basis of the endoscopic findings. As a result, the significance of bronchography to clinically evaluate lesions within the examination range of the fiberoptic bronchoscope has become greatly reduced.

The nomenclature presented in this chapter is based on extensive studies comparing the endoscopic and bronchographic findings. Nevertheless, at present we feel that the only types of cases in which bronchography is necessary for correct naming are deformed bronchi.

Left Upper Lobe Upper Division Bronchus

The upper division bronchus of the left upper lobe is one area in which the novice frequently experiences difficulty in naming the bronchi. This is partly because it is one of the most difficult areas in which to achieve deep insertion of the instrument and the angles of branching are varied, rendering orientation difficult in terms of relating the branching to the planes of the body.

The upper division bronchus consists of only two segmental bronchi. One of these corresponds, for all intents and purposes, to the two segmental bronchi B1 and B2 in the right lung and is therefore named B1+2. The other is B3. Naming of the bronchi in the upper division depends on the determination of the location of B1+2c. B1+2c, like B3a, distributes in a directly lateral direction (Fig. 40). Bifurcation of the upper division bronchus to B1+2 and B3 is seen in 72% of cases, in the remainder B1+2c branches directly from the upper division bronchus. B1+2 bifurcates to B1+2a+b and B1+2c in 94% of cases and B3 bifurcates to B3a and B3b+c in 95% of cases. B3a is the subsegmental bronchus branching most proximally from B3.

Another way of approaching the nomenclature of the subsegmental bronchi of the upper division is to name them proceeding in an anticlockwise direction from B1+2a,b,c, B3a,b,c.
TYPES OF BRANCHING AND THEIR FREQUENCY

Left Upper Lobe Lingular Bronchus

Generally B⁴ branches in a direction above B⁵, the former proceeding upward in a lateral direction and the later proceeding in a lower anterior direction. Proceeding directly from the bifurcation of the upper and lower lobe bronchi into the lingular bronchus the line described by the bifurcation of B⁴ and B⁵ can be seen to be vertical in 45% of cases and at an angle of 45° in 53%. The remaining 2% of cases consist of trifurcation to B⁴a, B⁴b and B⁵, each with an approximately equally sized lumen, or bifurcation parallel to that of the upper and lower lobe bronchi.

The lines of the bifurcation of the subsegmental bronchi of B⁴ and B⁵ are generally perpendicular to that of the bifurcation of their respective segmental bronchi. As is shown in Fig. 41, the naming of the subsegmental bronchi is based on B⁴a, which distributes in the most posterior/lateral direction, then, proceeding in a clockwise direction, B⁴b, B⁵a and B⁵b. Of the cases in which the bifurcation line of B⁴ and B⁵ is at 45° to that of the upper and lower lobe bronchi, B⁴a branches independently in about one third of cases. In this type of case also, naming is performed from B⁴a, proceeding to B⁴b and B⁵. In this type of case the subsegmental branching of B⁵ is more distal to that of B⁴ (Fig. 41).

In cases in which the bifurcation line of B⁴ and B⁵ is perpendicular to that of the bifurcation of the upper and lower bronchi, there are some, albeit few (5%), cases in which the subsegmental bifurcations are also perpendicular to the lobar bifurcation, in which case the lumens of the subsegmental bronchi appear arranged in a straight line. In such cases naming is performed from left to right, as shown in Fig. 42.

Left Lower Lobe Bronchus

In the left lower lobe, B⁶ branches dorsally soon after the bifurcation of the upper and lower lobe bifurcation. Peripheral to B⁶ is known as the basal bronchus. B⁶ branches into three subsegmental bronchi. However equal trifurcation is seen in
only 17%. In about 83% either bifurcation to two equally sized lumens or branching of a narrow subsegmental bronchus is seen, followed by branching of two larger subsegmental bronchi. Bifurcation to two equally sized lumens is seen in 13%, of which about 75% consist of B^6a+b and B^6c. Other types of bifurcation in this group are B^6a and B^6b+c and B^6b and B^6a+c, which last is the least frequent. In the type in which one narrow subsegmental bronchus branches first, followed distally by bifurcation of two larger bronchi, the proximal subsegmental bronchus is B^6a in 43%, B^6b in 20% and B^6c in 37%. B^6a is the subsegmental bronchus proceeding in the most upward direction, B^6b is lateral and B^6c is in an inferior direction, i.e. naming is performed clockwise beginning with B^6a (see Fig. 44).

In the basal bronchus there are several types of bifurcations and naming is performed moving from front to back, from B^8, B^9 to B^10 (Fig. 43). The most common type of bifurcation in the basal bronchus is B^8 and B^9+B^10 (62%) followed by B^8+B^9 and B^10 (22%) and trifurcation to B^8, B^9 and B^10 (16%). Concerning subsegmental branching, bifurcation to two subsegmental bronchi is the most common in B^8 and B^9, 87% and 89% (Fig. 45), respectively, while branching of B^10 to B^10a and B^10b+c is observed in 93% of cases. B^10a branches first, and b and c are named moving in a clockwise direction from B^10a (Fig. 44).

Fig. 41 Nomenclature of the lingular bronchus.

Fig. 42 Nomenclature of horizontally adjacent subsegmental bronchi of the lingular bronchus.

Fig. 43 Nomenclature of the left lower lobe bronchus.

Fig. 44 Nomenclature of left B^6 and B^10.

Fig. 45 Nomenclature of B^8 and B^9.
Right Upper Lobe Bronchus

There are many variations of branching in the right upper lobe (Table 2). The longitudinal folds of the membranous portion of the right upper lobe bronchus continue to B2, or to B1 and B2 or B2 and B3 in almost all cases (94%). In only 6% of cases do the longitudinal folds not continue to B2. In naming the segmental bronchi in the right upper lobe bronchus, first B2 is named based on the presence of the longitudinal folds, then B1 is recognized as the segmental bronchus bifurcating towards the apex of the lung. Naming the subsegmental bronchi in the right upper lobe is relatively simple (see Figs. 66—70).

There are four subtypes of trifurcation of equally sized bronchi in the right upper lobe, based on the type of branching and the arrangement of the segmental bronchi (Fig. 46).

Right Middle Lobe Bronchus

When approached directly from the middle lobe bronchus, the bifurcation line separating B4 and B5 is perpendicular in 39% of cases and at an oblique angle of about 45° in 56% of cases. The right middle lobe is different from the lingular lobe in the left lung in that B4 extends in a lateral direction while B5 proceeds in the direction of the mediastinum. Naming the subsegmental bronchi is performed moving in the pattern of capital N in reverse (Fig. 47), beginning with B4a, which is the most upward/lateral.

When the bifurcations of the segmental and subsegmental bronchi of the middle lobe bronchus are all perpendicular when viewed from the middle lobe bronchus (2% of cases) the subsegmental bronchi are named from a lateral to mediastinal direction (Fig. 48).

Right Lower Lobe Bronchus

B6 bifurcates from the posterior portion of the lower lobe bronchus. The bronchus distal to B6 is referred to as the basal bronchus.

Right B6, like left B6, divides into three segmental bronchi, but trifurcation is seen in only 6%. In the remaining 94% either left B6 divides first into two equally-sized lumens or else first one narrow segmental bronchus bifurcates followed by bifurcation of two other segmental bronchi. Bifurcation to two equally-sized lumens is seen in 9% of cases, among which bifurcation to B6a+b and B6c is seen in approximately two thirds. The most common type (38%) is bifurcation of a narrow B6a followed by bifurcation of wider B6b and B6c. Bifurcation to B6b and B6a+c is seen in 28% and bifurcation to B6c and B6a+B6b in 19%.

Of the subsegmental bronchi of right B6, B6a proceeds in the most superior direction, B6b in a lateral direction and B6c in an inferior direction. For this reason, first B6a is named, followed by B6 and B6c, proceeding in an anticlockwise direction (see Fig. 50).
Table 2  Types of segmental branching from the right upper lobe bronchus

<table>
<thead>
<tr>
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<th>Description</th>
<th>Diagram</th>
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<td>Trifurcation (38%) (see Fig. 46)</td>
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<td>Bifurcation of $B^1 + B^2$ and $B^3$ (28%)</td>
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<td>5</td>
<td>Bifurcation of $B^1 + B^3$ and $B^2$ (7%)</td>
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</tr>
<tr>
<td>6</td>
<td>Quadrifurcation (4%)</td>
<td><img src="" alt="Quadrifurcation Diagram" /></td>
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TYPES OF BRANCHING AND THEIR FREQUENCY

(b) V-type (26 %)  (c) Inverted V-type (12 %)  (d) Linear trifurcation (3 %)

Fig. 46 Subtypes of right upper lobe bronchial trifurcation.

Fig. 47 Nomenclature of the middle lobe bronchus.

Fig. 48 Nomenclature of horizontally adjacent subsegmental bronchi of the middle lobe bronchus.

Fig. 49 Nomenclature of the right lower lobe bronchus.

Fig. 50 Nomenclature of right $B^6$ and $B^{10}$.

Fig. 51 Nomenclature of right $B^8$ and $B^9$. 
Unlike in the left basal bronchus, in the right basal bronchus B7 branches in a mediastinal direction. As in the left basal bronchus, B7 is lacking in about 4% of cases.

B8, B9 and B10 are named in the same way as in the left lung, moving from and anterior to posterior direction (Fig. 49). The most common type of branching in the right basal bronchus is to B8 and B9+B10, which is seen in two thirds of normal cases, followed by B8+B9 and B10 (21%), while trifurcation is sometimes seen in 6%. Other variations include B8+B9a and B10 and B8+B9b and B10.

Concerning subsegmental branching, bifurcation is seen 99%, 87% and 83% of B7, B8 and B9, respectively, while in B10, branching to B10a and B10b+c is recognized in 93%.

In the basal bronchi of both right and left lungs the most lateral subsegmental bronchi are named a, and those distributing in a more inferior direction (i.e. towards the diaphragm) as b and c (Figs. 50, 51).

Normal Bronchoscopic Findings

Trachea and Carina (Fig. 52)

Fig. 52 From the trachea to the carina. Rings formed by the cartilage crescents can be seen in the anterior and lateral walls while the posterior wall is made up of the membranous portion. The membranous portion is made up of smooth muscle and contains many tracheal glands. Generally 5–7 longitudinal folds can be seen in the membranous portion but these tend to flatten with age. The carina can be seen in the foreground. The trachea bifurcates to the right and left main bronchi at the carina. About 2 cm from the carina the right upper lobe bifurcates from the right wall of the main bronchus.
Fig. 53  The left main bronchus and the bifurcation of the left upper and lower lobe bronchi. The membranous portion of the left main bronchus, in which several thick longitudinal folds can be seen, is in the posterior wall. The cartilaginous crescents can be seen extending around the anterior and lateral walls. The length of the left main bronchus is about 4 cm. The bifurcation of the left upper and lower lobe bronchi shows a variety of appearances, ranging from sharp to blunt. In the upper lobe bronchus bifurcates upward to the upper division and in an anterior direction to the lingular bronchus (the lower division bronchus). Longitudinal folds extending around the entire circumference of the bronchus and composed of elastic fiber bundles appear from the orifice of the lower lobe bronchus.
ANATOMY OF THE BRONCHUS

Fig. 54  Left upper lobe bronchus. The bifurcation of the left upper division bronchus and the lingular bronchus. In this figure circular folds composed of smooth muscle can be faintly distinguished in the left upper lobe bronchus. Usually the circular folds are clearly recognizable in the upper lobe bronchus as far as the lingular bronchus. The upper division bronchus extends upwards towards the apex and the lingular bronchus bifurcates in an anterior direction.

Fig. 55  Left upper lobe bronchus trifurcation of B₁+₂, B³ and the lingular bronchus. While the upper lobe bronchus generally bifurcates to the upper division and lingular bronchi, as was shown in the previous figure, in about 2% of cases it trifurcates to B₁+₂, B³ and the lingular bronchus, as is seen in this case. Since the upper lobe bifurcates directly to B₁+₂ and B³ in this case there is no area corresponding to the upper division bronchus. Circular folds are clearly seen in the lingular bronchus.
Fig. 56 Left B^1+2 and B^3. The left upper division bronchus branches to two equally sized lumens, one containing B^1+2, and the other containing B^3. In this case B^1+2 is short and immediately after bifurcating from B^3, bifurcation to the subsegmental bronchi occurs. In B^3, B^3a bifurcates in a lateral direction, after which B^3b and B^3c bifurcate. Circular folds made of smooth muscle can be recognized clearly in B^3. The length of B^3 varies from 0.5 to 12 mm.

Fig. 57 Left B^1+2 and B^3. Here the lumens of B^1+2 and B^3 are equal in size. The former bifurcates to B^1+2a+b and B^1+2c, followed by bifurcation of B^1+2a and B^1+2b. B^1+2a points in the direction of the apex of the lung, B^1+2b distributes in a posterior direction, while B^1+2c goes in a lateral direction. It is relatively rare to be able to simultaneously view the subsegmental bronchi of B^1+2 and B^3 as seen here.
ANATOMY OF THE BRONCHUS

Fig. 58 Left B^{1+2}a+b, B^{1+2}c and B^3. This is one type of trifurcation observed in the left upper division bronchus, with B^{1+2}c branching slightly proximal to B^{1+2}a+b and B^3. In cases of B^{1+2}c like this some subsequently bifurcate distributing to S^3 a and B^3 a is frequently smaller in diameter than the other subsegmental bronchi of B^3. This type of trifurcation in the upper division bronchus has been reported as occurring in 24% of cases by Shiozawa, 22% by Boyden, while in our experience it was seen in 28%. Generally B^3 and B^{1+2}c bifurcate in the same direction.

Fig. 59 Lingular bronchus; B^4, B^5. The left lingular bronchus (B^4, B^5) is the equivalent of the right middle lobe bronchus and the bifurcation to B^4 and B^5 tends to have a perpendicular axis. Circular folds due to smooth muscle can usually be seen in the lingular bronchus, which varies from 0.5 to 1.3 mm in length. In the lingular bronchus the most posterolaterally bifurcating bronchus is B^4 a, therefore the other bronchi are named B^4 b, B^5 a and B^5 b, moving from it in a clockwise manner.
Fig. 60 Lingular bronchus. This figure shows as far as the subsegmental bronchi of B^4 and B^5. The axis of the bifurcation of B^4 and B^5 is diagonal, relative to the axis of the body. Longitudinal folds can be seen in B^4a. In this case the bifurcation of B^5 appears to be rather distal. Its length can vary from 1–20 mm. In cases like this in which B^4a,b bifurcate in a hilar direction and the subsegmental area of B^5 is distal, the volume of S^4 is usually larger than that of S^5. This type is seen in 11% of cases.

Fig. 61 Lingular bronchus; B^4a+B^4b and B^5. In this case B^4a bifurcates independently and directly from the lingular bronchus, in a medial direction. In other words, this is a case of B^4a, B^4b+ B^5 bifurcation. This type has been reported in 20% of cases but in our experience was seen in 18%. Naming of the bronchi is based on the understanding that B^4a is the subsegmental bronchus distributing in the most posterolateral direction.
Fig. 62 Left B⁶; B⁶a and B⁶b+c. Left B⁶ bifurcates in a posterior direction 3–13 mm below the orifice of the lower lobe bronchus. After the bifurcation, circular folds due to smooth muscle can frequently be observed. B⁶ generally extends for a length of 1–6 mm before bifurcating to subsegmental bronchi. In this figure B⁶ branches to B⁶a and B⁶b+c. The frequency of this type of bifurcation has been reported as 22%, 29.1% and 20%, while in our experience it is 30%.

Fig. 63 Left B⁶; Trifurcation of B⁶a,b,c. In this case of clear trifurcation, circular folds can be observed in the segmental bronchus and longitudinal folds in the subsegmental bronchi. The frequencies of this type of trifurcation have been reported as 6%, 14.5% and 10%, as compared to 17.4% by our reckoning.
Fig. 64 Left basal bronchus; B^8, B^9, B^{10}. Trifurcation to B^8, B^9, and B^{10} is the most common in the basal bronchus and has been reported as occurring in 80%, and 69%, as opposed to 62% in our series. Occasionally circular or longitudinal folds can be recognized. All bifurcations of segmental and subsegmental bronchi in the basal bronchus are sharp.

Fig. 65 Left basal bronchus; B^{8}+B^9 and B^{10}. This type was reported as occurring in only 5% of cases, but we have experienced 22%. B^8a bifurcates independently in a lateral direction from the common lumen of B^8+B^9 and this type of B^8a bifurcation is seen in about 20% of this type of basal bronchi. Independent bifurcation of B^8a is also sometimes seen (7%) in the trifurcation type of B^8, B^9 and B^{10}. The longitudinal folds extending around the entire periphery of the bronchus are most clearly seen in the basal bronchus.
Right Bronchial Tree (Figs. 66–79)

Fig. 66 Right main bronchus; Right upper lobe bronchus and truncus intermedius. The right main bronchus has a large lumen, is short (about 2 cm) and the upper lobe bronchus branches laterally from it. Generally 5–7 longitudinal folds are seen in the main bronchus, of which 2–3 diverge towards the upper lobe bronchus, while the remainder continue to the truncus intermedius. The longitudinal folds continuing from the main bronchus to the upper lobe bronchus extend to B^2. Regular ridges can be seen on the main bronchus and the truncus intermedius, showing the outline of the horseshoe-shaped cartilage.

Fig. 67 Right upper lobe; Trifurcation of B^1, B^2, B^3. One type of trifurcation seen in the upper lobe. The longitudinal folds continuing from the right main bronchus can be seen running to B^2 and the bifurcation of B^2 and B^3. B^1 bifurcates towards the apex of the lung. B^1b bifurcates in a direction anterior to B^1a. B^2a bifurcates in a posterior direction and B^2b bifurcates in a lateral direction, below B^2a. B^3a distributes laterally and B^3b distributes to the inferoanterior region of the upper lobe.
Fig. 68 Right upper lobe; $B^1+ B^2$ and $B^3$ bifurcation type. The small irregularity at the bifurcation of $B^1$ and $B^3$ is probably due to a small defect in the lamina propria at that site.

Fig. 69 Right upper lobe; $B^1$ and $B^2+ B^3$ bifurcation type. First $B^1$ bifurcates towards the apex, then $B^2$ and $B^3$ bifurcate from a common lumen. The longitudinal folds extending from the membranous portion of the main bronchus can be seen to continue towards $B^2$. In $B^1$ longitudinal folds finer than in $B^2 + B^3$ can be seen. In this type of case the volume of $S^1$ will be relatively larger than those of $S^2$ or $S^3$. 
Fig. 70 Right upper lobe bronchus; Quadrifurcation type. This is one of the so-called quadrifurcation types seen in the right upper lobe bronchus. This type has been reported as occurring in 14% and 10% of cases by Boyden and Yamashita, respectively. According to our data it is seen in only 4% of cases. Boyden referred to this type as the quadrivial type and named the types of bifurcations as $B^1, B^2a, B^2b, B^3$, or $B^1 + B^2 + B^3$. The types of quadrifurcation named by Yamashita were $B^3a, B^3b$ and $B^3a, B^3b, B^3$. Our nomenclature for this figure is $B^1, B^2a, B^2b, B^3$.

Fig. 71 Truncus intermedius. Looking peripherally from the truncus intermedius the three large bronchial lumens arranged in an almost straight vertical line can be seen. This is a characteristic feature of the truncus intermedius. The middle lobe bronchus can be seen in the upper portion of the figure, branching upwards. In this case $B^6$ bifurcates in a somewhat lateral direction. $B^7$ can be seen to branch in a mediastinal direction and $B^8$ and $B^9 + B^{10}$ can also be seen bifurcating to the basal segments.
Fig. 72  Truncus intermedius (in a case with an anomalous bronchus). Usually no bronchus can be recognized between B6 and B10. However, in a very few cases an anomalous sub-superior bronchus B* can be seen branching in a posterior direction, immediately distal to B6. There are differences in the size of such anomalous bronchi and the range to which they distribute. The authors' data suggests such an anomalous bronchus in 4% of cases, but Yamashita reported a figure of 28.1%.

Fig. 73  Middle lobe bronchus. In this figure B4 and B5 bifurcate laterally and medially, respectively. While the middle lobe bronchus is extrapulmonary anatomically, its structure resembles that of intrapulmonary segmental bronchi. As a result, it is similar to the left lingular bronchus in that it has circular folds of smooth muscle. The length of the middle lobe bronchus is longer and narrower than other segmental bronchi, approximately 1.0 cm in length with a width of 7–8 mm. Since its structure does not contain cartilage arches it easily becomes stenotic as a result of external compression.
Fig. 74  Middle lobe bronchus. B^4 and B^5 bifurcate laterally and medially, respectively. The subsegmental bronchi of B^5 can be seen branching in a superior and inferior direction. Since the lumen of B^4 appears smaller than that of B^5 in this case, it is probable that in this case S^5 is larger than S^4. Circular mucosal folds and branching vessels can be seen. Usually the lumens of B^4 and B^5 are approximately equal in size, but the lumen of B^4 is smaller in about 20% of normal cases, while that of B^5 is smaller in about 10% of cases.

Fig. 75  Right B^6; B^6a+c and B^6b bifurcation type. B^6 is the largest of the segmental bronchi and it distributes in a posterolateral direction. In 80% of normal cases the subsegmental bifurcation of B^6 includes a lumen commonly shared by two of the subsegmental bronchi before they branch from each other. In this case B^6a and B^6b share a common lumen before they branch from each other, hence the nomenclature. The frequency of this type is seen in about 28% of cases. Normally the subsegmental bifurcations are sharp, but in the case of B^6a a blunt subsegmental bifurcation is seen in about 10% of normal cases.
Fig. 76 Right $B^6$; $B^6a$ and $B^6b+c$ bifurcation type. This is the most commonly seen type of subsegmental branching of $B^6$. $B^6a$ distributes in a superior direction, $B^6b$ in a lateral direction and $B^6c$ in a medial direction.

Fig. 77 Right basal bronchus. In the basal bronchus $B^7$ branches most proximally in a median direction. $B^7a$ and $B^7b$ branch in dorsal and ventral directions, respectively. As is shown here, the most common bifurcation of $B^8$, $B^9$, $B^{10}$ is to $B^8$ and $B^{9+10}$. 
Fig. 78  Right basal bronchus; Bifurcation of B₈+B⁹ and B¹⁰. This type of bifurcation is seen in 21% of cases. B₈a proceeds in an anterior direction, B⁹ laterally and B¹⁰ dorsally. The direction of both B₈a and B⁹a is lateral, while that of B₈b and B⁹b is towards the mediastinum. The direction of B¹⁰a is dorsal, B¹⁰b is lateral and B¹⁰c is medial, towards the mediastinum.

Fig. 79  Right B¹⁰; B¹⁰ and its subsegmental bronchi. Circular folds can be seen, as can longitudinal folds. B¹⁰a branches in a lateral direction, B¹⁰b+c possesses a long common lumen of 5-10 mm. B¹⁰b bifurcates in a lateral direction and B¹⁰c bifurcates in a medial direction.
Anomalous Bifurcation of the Right Upper Lobe Bronchus

Case 1 (Figs. 80–82)

The right upper lobe bronchus in this case with an anomalous bronchus (Fig. 80) was slightly narrower than usual. From the upper lobe bronchus two segmental bronchi of almost the same size bifurcate. Slightly distal to this bifurcation, in the lateral wall of the truncus intermedius, is an anomalous bifurcation which is in a slightly posterior direction. On the basis of the bronchograms (Figs. 81, 82) the authors named this B^2.

The right B^1 of this case resembles the distribution of left B^{1+2}a+b, while B^3 extends in a slightly raised direction. We considered the anomalously bifurcating bronchus as B^2, but on the lateral bronchogram it was seen to extend below B^3. This type of anomaly is observed on occasion, albeit rarely, and in addition to this type sometimes an azygos lobe bronchus distributes to the apex proximal to the usual upper lobe bronchus (bifurcating from the right lateral wall of the lower trachea).

Fig. 80

(a) Segmental bronchi branching from the left upper division bronchus.
(b) Anomalous bifurcation from the right truncus intermedius.
(c) Anomalous segmental bronchus branching from the truncus intermedius and its subsegmental bronchi.
In the type of anomaly shown here (Figs. 83, 84) \( B^2 \) alone branches away from the lateral wall of the right upper lobe bronchus. The orifice of \( B^2 \) appears in this photograph as a semicircle. The area to which this anomalously branching bronchus distributes is not as extensive as that of the normal \( B^2 \) and therefore in this case \( B^1 \) and \( B^3 \) distribute to almost the entire upper lobe. This was a case of asthma which underwent detailed examinations for a persistent cough.
Fig. 83  Anomalous bifurcation of the right upper lobe bronchus.

Fig. 84  Bronchogram. The arrow indicates the bifurcation exhibiting abnormal findings. The indicated bronchus branches directly away from the upper lobe bronchus and distributes to the posterior portion of the upper lobe.
Classification of Fiberoptic Bronchoscopic Findings

The classification of fiberoptic bronchoscopic findings shown in Table 3 is employed in the Department of Surgery of Tokyo Medical College, and is based on the proposal of the Committee for Classification of Bronchoscopic Findings of the Japan Lung Cancer Society. This classification is designed to provide a uniform framework to analyze the findings observed in the bronchus, not only in cases of lung cancer, but also in the wide range of conditions experienced in daily clinical work.

Bronchoscopic Findings of Lung Cancer

In the not-so-distant past, when fiberoptic bronchoscopy was in its infancy, the range of terminology to describe the appearance of cases of lung cancer was limited and there were only three terms to describe invasion, a) vascular engorgement, b) mucosal irregularity, c) lack of clarity of the cartilage rings. However, comparison of endoscopic findings with the pathological findings has resulted in significant new knowledge and also the development of terminology to accurately describe the macroscopic appearance.

By application of the analytical framework shown in Table 3 it should be possible to accurately evaluate exactly what portion is involved by invasion, and by recognition of the type of proliferation, to arrive at a fair estimation of the histologic type. Of course not only observation, but also biopsy, is necessary for a definitive diagnosis.
Table 3  Classification of bronchoscopic findings
(Revised classification by the Japan Lung Cancer Society)

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<th>1. Endoscopic evaluation of bronchial structure</th>
<th>4) Clear engorgement of neoplasm-related vessels</th>
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<td>5) Tubercle</td>
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<td>3) Absence of vessels</td>
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<tr>
<td>4) Engorgement of neoplasm-related vessels</td>
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<td>5) Irregular mucosal surface</td>
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<tr>
<td>6) Ulceration of the bronchial wall</td>
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<td>7) Tumor (nodular, multinodular,</td>
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<tr>
<td>granular surface, irregular surface)</td>
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<tr>
<td>8) Necrosis</td>
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<td>9) Abnormalities in the mucosal folds</td>
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<tr>
<td>(thickening, indistinctness, disappearance)</td>
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<td>B : Submucosal</td>
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<tr>
<td>a) Lamina propria</td>
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<tr>
<td>i) Normal findings</td>
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<tr>
<td>1) White longitudinal mucosal folds</td>
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<td>2) Vascular network</td>
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<td>ii) Abnormal findings</td>
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<td>1) Swelling (edema)</td>
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<td>2) Redness</td>
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<td>3) Bleeding</td>
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<td>4) Punctuation</td>
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<tr>
<td>5) Engorgement of non-neoplasm-related vessels</td>
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<tr>
<td>6) Engorgement of neoplasm-related vessels</td>
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<tr>
<td>7) Irregular mucosal surface</td>
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<tr>
<td>8) Indistinct cartilage ring and circular folds</td>
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<tr>
<td>9) Ulceration of the bronchial wall</td>
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<tr>
<td>10) Enlargement of mucosal glands</td>
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<tr>
<td>11) Transparent mucosal anthracosis</td>
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<td>12) Mucosal atrophy</td>
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<td>13) Mucosal thickening</td>
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<td>14) Tumor (nodular, multinodular,</td>
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<tr>
<td>smooth surface, irregular surface)</td>
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<tr>
<td>15) Abnormalities in the mucosal folds</td>
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<td>(irregularities, thickening, indistinctness, disappearance)</td>
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<tr>
<td>b) Smooth muscle layer</td>
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<tr>
<td>i) Normal findings</td>
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<tr>
<td>1) Circular folds</td>
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<td>2) Protrusion of bronchial cartilage</td>
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<tr>
<td>ii) Abnormal findings</td>
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<tr>
<td>1) Mucosal atrophy</td>
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<td>2) Mucosal thickening</td>
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<td>3) Tumor (smooth surface)</td>
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<td>C : Extramuscular layer</td>
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<tr>
<td>i) Normal findings</td>
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<tr>
<td>1) Cartilage crescent</td>
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<td>2) Projection of bronchial cartilage</td>
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<td>ii) Abnormal findings</td>
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<td>1) Mucosal atrophy</td>
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<td>2) Mucosal thickening</td>
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<tr>
<td>3) Accentuated irregular folds</td>
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<td>4) Tumor (smooth surface)</td>
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<td>5) Clear engorgement of neoplasm-related</td>
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<td>vessels</td>
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<td>D : Extramural layer</td>
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<tr>
<td>i) Normal findings</td>
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<td>1) Unremarkable</td>
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<td>ii) Abnormal findings</td>
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<td>1) Compressed stenosis</td>
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<td>2) Accentuated irregular folds</td>
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<tr>
<td>3) Transparent lymph nodes</td>
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<td>2. The bronchial lumen</td>
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<td>1) Stenosis</td>
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<td>a. Due to exposed lesion</td>
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<td>b. Due to submucosal lesion</td>
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<td>c. Due to lesion beyond the smooth muscle</td>
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<td>layer</td>
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<td>d. Due to external compression</td>
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<td>2) Obstruction</td>
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<td>a. Due to exposed lesion</td>
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<td>b. Due to submucosal lesion</td>
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<td>c. Due to lesion beyond the smooth muscle</td>
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<td>d. Due to external compression</td>
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<tr>
<td>3) Engorgement</td>
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<td>4) Compression</td>
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<td>5) Abnormal branching</td>
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<td>6) Abnormal findings at bifurcation</td>
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<tr>
<td>a. Widening of bifurcation</td>
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<td>b. Compression</td>
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<td>c. Construction</td>
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<td>3. Pathological substance</td>
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<td>1) Abnormal secretions</td>
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<td>2) Bleeding</td>
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<td>3) Stones</td>
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<td>4) Foreign bodies</td>
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<td>4. Disturbance of movement</td>
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<td>1) Abnormal movement during respiration</td>
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<td>2) Abnormal movement on coughing</td>
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Bronchoscopic Findings and Their Pathological Significance

The classification of all the possible findings that can be exhibited by the most common pulmonary diseases is extremely difficult. This is because even in different cases of the same disease, the findings can vary greatly, depending on the individual.

The fiberoptic bronchoscopic findings can show a particularly varied range of findings depending on the relationship between the lesion and the bronchus, that is depending on the site and the clinical stage, and in fact lung cancer can present all the findings possible to be seen except, generally, for deep ulceration and purulent secretions.

However, these latter two conditions are sometimes seen in cases undergoing radiotherapy (ulcer formation) or in which pneumonic distal and purulent secretions to the lesion have occurred as secondary changes. For detailed explanation of the characteristic endoscopic findings of lung cancer according to histologic type and clinical stage, see Chapter 4.

Great differences are also seen in relation to the type and stage of tuberculosis. The exacerbated condition of the acute stage shows a high degree of inflammation but as anti-tuberculosis agents begin to take effect, the findings of redness, swelling, bleeding and increased secretions disappear. Subsequently gradually fiberoptic changes, that is chronic inflammatory changes, are recognized, followed by disappearance of the mucosal folds. As the curative course progresses cicatricial formation is seen with varying degrees of stenosis or obstruction.

It must therefore be understood that the endoscopic appearance changes in accordance with the site occupied by the lesion, stage, histologic type and course. Thorough roentgenographical examination prior to fiberoptic bronchoscopy increases accuracy of the analysis of findings.

Analysis of Fiberoptic Bronchoscopic Findings

Pathological changes should be considered from the point of view of whether the site of changes is in the bronchial mucosal epithelium, within the bronchial wall (subepithelial) or beyond the bronchial wall. Such evaluation of the layers and site involved should be performed in every type of disease affecting the bronchus, whether it be inflammation, sarcoidosis or a tumor. Figure 85 shows a classification of findings based primarily, but not exclusively, upon situations encountered in lung cancer.

Usually in the case of bronchitis the type of findings observed are those of 1a, primarily mucosal (increase of goblet cell hyperplasia, squamous cell metaplasia) and 2a, primarily submucosal, in Fig. 85. During the curative course of bronchial
tuberculosis type 2b intramural type changes (tuberculous granuloma, cicatricial tissue) are most commonly observed. In sarcoidosis, types 1a (squamous cell metaplasia), 2b (intramural granuloma) and 2c (lymph node granuloma) can be recognized. In most cases of benign tumors, type 1b nodular protrusions are most frequent but on occasion they can be covered by the bronchial mucosa, appearing as type 2b.

The appearance of lung cancer varies according to the histologic type, with squamous cell carcinoma generally appearing as type 1 and small cell carcinoma and adenocarcinoma appearing as type 2. Further information concerning this is presented in the chapter on the characteristics of each histological type of lung cancer.

1) Primarily mucosal type

(a) Superficial infiltrating type
(b) Nodular infiltrating type
(c) Polypoid type

2) Primarily submucosal type

(a) Subepithelial type
(b) Intramural type
(c) Extramural type

Fig. 85 Classification of endoscopically viewed pathological findings.
Background Knowledge Necessary for Correct Analysis of the Bronchoscopic Findings of Lung Cancer

Fiberoptic Bronchoscopic Biopsy Findings

Close examination of the relationship between the tumor and the adjoining bronchial mucosa is extremely important. As has been already emphasized, one of the most basic points is to observe whether the tumor proliferates in the bronchial epithelium protruding into the lumen or whether it grows covered by bronchial epithelium, since this does have some relationship with the histology. Again, different histologic types display tendencies in terms of site of occurrence: 60–70% of squamous cell carcinomas of the lung and almost all small cell carcinomas originate in segmental or larger bronchi and 90% of adenocarcinomas originate distally. Combining data on the site of origin and the type of proliferation can thus be extremely important in estimating the histology. Using this approach at our institution, our estimation of histologic type during bronchoscopy has proved correct in 90% of cases on examination of biopsy material.

Most cases of central type squamous cell carcinoma appear exposed in the bronchial lumen, but a small number of cases proliferate partially submucosally. In peripherally originating cases of squamous cell carcinoma, abnormal findings can be recognized upon metastasis to regional lymph nodes or invasion of hilar bronchi by metastatic lymph nodes. Metastatic invasive lesions also display a strong tendency to appear exposed in the bronchial lumen, which agrees well with the strong tendency seen histologically for squamous cell carcinoma to proliferate replacing bronchial mucosa.

In small cell carcinoma submucosal proliferation is seen in the primary lesion, regional lymph nodes and surrounding bronchi. Intermediate cell type small cell carcinoma tends to appear exposed in the bronchial lumen more frequently than oat cell carcinoma.

Most cases of adenocarcinoma proliferating in hilar bronchi or metastatic to regional lymph nodes proliferate submucosally, but some cases appear protruding in the bronchial lumen. Large cell carcinoma can grow breaking through the epithelium into the lumen but most cases largely grow subepithelially.

Lung tumors metastatic from the esophagus, breast, colon, kidney and testis also show a strong tendency to grow subepithelially, although some do grow exposed in the bronchial lumen.

Because of the clear difference in the type of proliferation and development of squamous cell carcinoma in comparison to other histologic types of carcinoma, the endoscopic findings are of great aid in estimating the histologic type.
Endoscopic Findings of Superficial Infiltration of Central Type Carcinoma According to Site and Depth of Invasion as Determined Histologically

Squamous cell carcinoma displays a tendency to replace bronchial mucosal epithelium and grow exposed as a tumor in the bronchial lumen. Adenocarcinoma and small cell carcinoma, on the other hand, tend to proliferate by invading submucosally. Since squamous cell carcinoma grows invading the bronchial epithelium itself, it is relatively easy to grasp the extent of invasion. In cases of cancer appearing in the bronchial lumen it should always be possible to detect the extent of the invasion endoscopically. Although this is simple in the case of carcinomas exhibiting polypoid or nodular growth\(^{96}\), it is difficult to determine the exact extent of superficial infiltration in cases proliferating primarily within the bronchial epithelium\(^3,95\). For the purpose of facilitating the endoscopic recognition of carcinoma in situ or early stage cancer, we compiled Fig. 86 from a comparison of the results of endoscopic examination and pathological review of the borders of resected specimens of early stage central type squamous cell carcinoma as well as the border area of more advanced cases.

In reading the appearance of the superficial invasion type, close analysis of the mucosal folds is important\(^3,81\). The various types of proliferation and their histologic appearance are shown in Figs. 87—90.

Endoscopic Findings in Relation to the Depth of Submucosal Invasion (Primary Submucosal Type)

Since peripherally originating adenocarcinoma, small cell carcinoma and large cell carcinoma tend to proliferate under the bronchial mucosal epithelium\(^76\), even if there is thickening of the mucosal folds, or a polypoid protuberance, the surface appears glossy. Usually there is no attachment of necrotic substances to the surface, and enlarged vessels that appear not to be neoplastic vessels are seen on the surface of the tumor.

Changes in the mucosal folds of the primarily submucosal type are closely related to the question of what layers of the bronchial wall are involved, in addition to the quantity of tumor.

In cases of small amounts of invasion to the lamina propria and extramucosal layer, thickening of the bronchial wall is not seen and the folds caused by the elastic fiber bundles appear normal (Fig. 91).

With increased invasion of the lamina propria and extramucosal layer, the whitish longitudinal folds become unrecognizable and the mucosa shows irregular swelling and protrusion with edematous changes (interrupted undulating surface, Fig. 91).

Due to thickening of the extramucosal layer as a result of proliferation of malignant tissue within the relatively fixed area circumscribed by cartilage, a variety of effects can be seen in the mucosal epithelium and lamina propria including secondary longitudinal folds. If these are secondary it implies that the normal folds first disappeared.
BRONCHOSCOPIC DIAGNOSIS

Fig. 86 Findings in the bronchial mucosal wall.
(a) Normal mucosal folds. The elastic fiber bundles in the lamina propria can be seen through the mucosal epithelium.

(b) Thickened undulating mucosal folds. Thickened uneven folds due to cancerous invasion of the mucosal epithelium. This condition is frequently seen in squamous cell carcinoma. The elastic fiber bundles of the lamina propria cannot be seen.

(c) Intraepithelial proliferation. In a few cases of squamous cell carcinoma the margin of the tumor can exhibit proliferation between layers of normal epithelial cells and normal basement membrane.

(d) Irregular mucosal surface. Cancer invading the mucosal epithelium, lamina propria, muscular layer and extramucosal layer appears as an irregular mucosal surface, with loss of the mucosal folds. This condition is also frequently seen in squamous cell carcinoma.

(e) Ulcer formation. In cases of proliferation of cancer from the mucosa as far as the extramuscular layer, exfoliation of the surface layer, resulting in ulcer formation is sometimes seen. Most such cases are squamous cell carcinoma.

(f) Irregular surface with engorged neoplasm-related vessels. When proliferation proceeds beyond the condition described in (d), vessels related to the neoplasm can be readily observed due to their engorged appearance.

(g) Compression and accentuated irregular folds. When the proliferation of malignant tumor is primarily in the extramucosal layer and invasion has not yet involved the smooth muscle layer, lamina propria or mucosal epithelium, the thickening of the extramucosal layer causes irregularity of the depth of the normal mucosal layers and also stenosis of the bronchial lumen. This compression also causes secondary accentuation of irregular folds. Such findings are most commonly seen in adenocarcinoma, small cell carcinoma and large cell carcinoma.

(h) Subepithelial invasion. Subepithelial proliferation causes loss of the mucosal folds and the mucosal surface becomes shiny. This generally represents a more extensive range of invasion than in (g) above, and is also most commonly seen in adenocarcinoma, small cell carcinoma and large cell carcinoma.
Fig. 87 Normal bronchial mucosa showing regular mucosal folds due to elastic fiber bundles.

Fig. 88 Squamous cell carcinoma showing intraepithelial invasion.
1. Elastic fiber bundles  2. Smooth muscle
Fig. 89 Squamous cell carcinoma invading as far as the lamina propria.

Fig. 90 Squamous cell carcinoma proliferating beyond the smooth muscle layer. The elastic fiber bundles and smooth muscle are exposed due to ulcer formation on the tumor surface.
1. Elastic fiber bundles 2. Smooth muscle
These folds are glossier than the normal longitudinal folds and are thicker and more swollen, while the depression between them is more marked (accentuated irregular folds). These folds are due to thickening of the extramuscular layer as a result of tumor proliferation and the thickening causes stenosis, compression and the appearance of confluent folds. The authors adapted the index that Reid developed to quantitatively measure thickening of the bronchial wall in cases of chronic bronchitis (i.e. thickness of the extramuscular layer/greatest distance from the cartilage to the basement membrane) to measure the maximum thickness of the extramuscular layer from the inner wall of the cartilage in cases of adenocarcinoma and found a value of over 0.5 in all cases (Figs. 86, 87, 92).
When there is little or no invasion of the lamina propria or the muscular layer it can be thought that there is probably no thickening of these layers. If the tumor invades the lamina propria, this layer becomes thickened and the thickened accentuated irregular folds that were formed by compression disappear. This is because of invasion to the deep depression between the accentuated irregular folds. The surface above subepithelial invasion appears glossy (subepithelial invasion, Fig. 93). Occasionally bridging folds such as seen by gastroscopy in cases of submucosal tumors are seen among the longitudinal folds.

Even in the primarily submucosal type the tumor can break through the mucosal epithelium in places and necrosis can be seen in such sites (Fig. 93). Stenosis can be caused by compression from extramural lymph nodes but sometimes no abnormality is recognized in the mucosa or mucosal folds.

It is more difficult to correctly grasp the exact range and extent of invasion, particularly the border of the malignant lesion, than in cases of the primarily mucosal type. In cases in which a submucosal tumor is suspected, that site should be biopsied or transbronchial aspiration biopsy (TBAB) performed in order to obtain a histologic or cytologic diagnosis.

1. Accentuated irregular folds
2. Subepithelial invasion
3. Irregular surface, where the malignant lesion can be seen exposed.

Fig. 93 Cross-section of lobar bronchus of a squamous cell carcinoma case originating in the periphery of the lung.

Analysis of Vascular Findings

The vascular findings, particularly the color of vessels, are the most indicative of the condition of the submucosal area. Table 4 is a classification of the vascular findings in the bronchial wall as observed bronchoscopically (Figs. 94–99).
Fig. 94 Normal vascularization. Regular distribution of blood vessels branching in the upper division and lingular bronchus.

Fig. 95 Vascular engorgement. Invasion of adenocarcinoma in the left main bronchus. Engorged vessels can be seen in the surface of the thickened longitudinal folds of the membranous portion. In the area where it appears the tumor has broken through the mucosal epithelium. Engorgement of corkscrew-like vessels can be seen.
Fig. 96 The right lower lobe bronchus is obstructed and submucosal tumor invasion can be seen from the truncus intermedius to the middle lobe bronchus. The tumor is exposed in the orifice of the lower lobe bronchus. In the right wall of the truncus intermedius, vascular engorgement connecting with the slight irregularity in the membranous portion suggests invasion of the lamina propria. The left wall of the truncus intermedius suggests extramuscular layer invasion. Biopsy of the orifice of the lower lobe bronchus revealed squamous cell carcinoma.

Fig. 97 These are the findings in the same case shown in the previous figure, after intravenous injection of 5 ml (10 w/v%) fluorescein via the medial cubital vein, as seen through a filter (Kodak Wratten 12©). The vessels in the membranous portion of the truncus intermedius can be seen to consist of many overlapping vessels. This method simplifies distinguishing between submucosal invasion and extramuscular layer invasion.
Fig. 98 A tumor can be seen invading the extramuscular layer of the anterior wall (right) of the left upper division bronchus. B^{1+2} and B^3 are stenotic due to tumor invasion and the bifurcation between them is blunt and swollen. Red punctation is recognized at the area of submucosal bronchus in the upper division bronchus. Biopsy of the bifurcation of B^{1+2} and B^3 yielded a diagnosis of adenocarcinoma.

Fig. 99 The fluorescence bronchial angiography findings of the same case shown in the previous figure. Vascular findings are seen in detail, but they do not appear to extend over a wider area than when examined by the conventional technique. The mucosal surface irregularity is more clearly seen by this technique and distinguishing between normal longitudinal folds and wide accentuated irregular folds caused by invasion of the smooth muscle layer is simplified.
Normal vessels can be observed branching evenly throughout the lamina propria and are not observed in the mucosal epithelium (Fig. 100a). Bronchitis causes many changes in the lamina propria, such as vascular engorgement, increase in the number of vessels, redness, invasion of inflammatory cells etc., and these are seen through the mucosal epithelium (Fig. 100b).

Figure 101 shows the resected specimen in a case of squamous cell carcinoma. Invasion can be recognized from the left upper lobe bronchus to the main bronchus and the border of malignant and normal areas is clear (arrow). Vessels can be seen branching under the normal mucosal epithelium on the left. Most of the blood vessels disappear abruptly at the margin of the lesion. One vessel can be seen developing through the epithelium connecting to beneath the lesion (white arrow), after which it disappears (Fig. 100c).

![Fig. 100 Bronchoscopic classification of vascular patterns.](image)

(a) Normal vascular pattern  
(b) Engorgement of vessels  
(c) Intraepithelial invasion prevents observation of blood vessels  
(d) Engorged vessels, including neoplastic vessels covered by mucosa  
(e) Engorged vessels, including neoplastic vessels, exposed in the bronchial wall
The reason why blood vessels and white longitudinal folds cannot be seen in the area of intraepithelial invasion of squamous cell carcinoma is because of loss of transparency due to the densely proliferating malignant cells\(^4\). As invasion develops in the bronchial wall, neoplasm-related vessels appear (Table 4) which by their dilatation and distribution pattern appear to be supplying the lesion with the maximum nutrition possible for their number.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Classification of vascular findings as observe via the fiberoptic bronchoscope</th>
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<tbody>
<tr>
<td>1. Non-neoplasm-related</td>
<td>3. Distribution pattern</td>
</tr>
<tr>
<td>(1) Engorgement</td>
<td>(1) Tree-like branching</td>
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<tr>
<td>(2) Disappearance</td>
<td>(2) Irregular network</td>
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<tr>
<td>2. Neoplasm-related</td>
<td>(3) Corkscrew-like</td>
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<tr>
<td>(1) Engorgement</td>
<td>(4) Numerous fine parallel tracks</td>
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<td>(2) Stenosis</td>
<td>4. Red flecking</td>
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<tr>
<td>(3) Abruption</td>
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<td>(4) Disappearance</td>
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</table>

In adenocarcinoma and small cell carcinoma, which proliferate primarily submucosally, various kinds of vascular engorgement can be seen, depending on the extent of proliferation and the distance between the invasion and the mucosal epithelium. Generally the previously existing normally distributing vessels are dilated, showing increasingly marked engorgement as they approach the lesion (Fig. 100d). With further proliferation destruction of the epithelium and the development of irregular neoplasm-related vessels can be observed.
Biopsy Methodology Based on Analysis of Bronchial Wall Findings

For the bronchoscopist to develop an effective biopsy technique he or she must become familiar with the histologic findings\(^1\) that correspond to the various kinds of endoscopic findings. Analysis of the histologic findings can provide important information regarding the evaluation of the macroscopic endoscopic appearance. Furthermore, in cases in which a definitive diagnosis of histologic type has already been made, it may be necessary to perform further biopsies to clarify the type of invasion and development of the lesion.

In routine clinical work it is common to experience cases in which the endoscopist is sure that the disease is malignant yet in which biopsy yields only bronchial mucosa. This is frequently caused by insufficiently deep biopsy bite in cases involving the extramuscular layer. Conversely, in some cases in which the endoscopic findings are suspicious of intramural lymph node invasion, biopsy of apparently normal areas apart from such invasion may be shown to contain malignant cells on histologic examination.

Generally it is possible to obtain a biopsy bite as deep as the extramuscular layer by fiberoptic bronchoscopy and at bifurcations a bite as deep as the cartilage is possible. The analysis of endoscopic findings and histologic diagnosis can be likened to the two wheels of a cart, each supporting and serving to promote the progress of the other.

Cytologic examinations, apart from brushing cytology of superficially invading squamous cell carcinoma and TBAB in cases of pathological changes beyond the bronchial wall, provides little information pertinent to the evaluation of fiberoptic bronchoscopic findings.

In particular, in cases of pathological changes in the lamina propria or deeper areas harvesting of diagnostic cytological material from the mucosal surface is impossible, while TBAB only yields information concerning the puncture spot. It is therefore important to analyze the findings three-dimensionally, evaluating both the lateral extent and the depth of findings, based on a thorough knowledge of the histologic structure of the organ. This holds true for all endoscopy procedures, including gastrofiberscopy.

As progress is made in the analysis of findings in the bronchial wall according to the mural structure, the role and effectiveness of fiberoptic bronchoscopic biopsy will increase even more.

Nodular Proliferation

Tumors proliferating as nodular protrusions not covered by normal mucosa are the easiest cases in which to perform biopsy. Mucin or necrotic material adhering to the surface should be avoided and a deep bite should be made in order to obtain viable tumor cells (Fig. 102). Even when only necrotic materials are obtained, sometimes a diagnosis can be made on the basis of remaining keratinized materials or clusters of non-viable ghost tumor cells. This type of tumor is most commonly seen in squamous cell carcinoma (Fig. 103).
Fig. 102 Biopsy of nodular infiltration.

Fig. 103 Histologic findings of the case shown in Fig. 126. This biopsy specimen was harvested from the tumor protruding exposed in the bronchial lumen. Tumor nests can be seen in map-like arrangement in this moderately well differentiated squamous cell carcinoma. Neoplastic blood vessels which were observed bronchoscopically can be seen in the tumor. All blood vessels in malignant tumors are considered, by definition, to be neoplastic.

Superficial Infiltration

Endoscopic localization of the extent of superficially infiltrating lesions can be difficult. To obtain diagnostic materials biopsy should be performed at sites showing the greatest extent of irregularity or unevenness and at bronchial
bifurcations that appear widened (Fig. 104). In order to estimate the extent of resection necessary, biopsies should also be performed at the apparent border with normal tissue and in surrounding normal tissue. This type of case is seen in central type squamous cell carcinoma (Fig. 105).

Fig. 104 Biopsy of superficial infiltration.

1. Squamous cell carcinoma replacing the mucosal epithelium
2. Lamina propria
3. Smooth muscle
4. Extramuscular layer
5. Squamous cell carcinoma invading the bronchial gland

Fig. 105 Biopsy specimen of the case shown in Fig. 119. Biopsy obtained material as deep as the extramuscular layer. Squamous cell carcinoma replaces the mucosal epithelium and pathological changes can be seen as deep as the lamina propria and in the bronchial gland as far as the extramuscular layer. These findings are seen in superficially infiltrating central type early stage lung cancer.
Submucosal Invasion

The target site for biopsy of submucosally proliferating lesions is the area of most marked elevation (Fig. 106). Tumor and ciliated columnar epithelium are obtained. This type of tumor is most commonly seen in adenocarcinoma, small cell carcinoma and large cell carcinoma (Fig. 107).

![Fig. 106 Biopsy of submucosal invasion.](image)

![Fig. 107 Histologic findings of the case shown in Fig. 153. The tumor grew submucosally, involving the smooth muscle. The specimen was crushed somewhat on biopsy and as a whole, stains darkly. These findings are characteristic of small cell carcinoma. The cytoplasm of small cell carcinoma is scanty and the mechanical method of obtaining the biopsy specimen generally causes crushing and leakage of nucleic acid, with the resultant characteristic dark stain of small cell carcinoma biopsy specimens.](image)
Extramuscular Invasion

Many peripherally originating tumors invade and proliferate in the extramuscular layer of the bronchial wall within areas that can be examined by the fiberoptic bronchoscope. In such cases a shallow biopsy bite will obtain only normal tissue (Fig. 108). Cases in which the endoscopic findings, but not the pathological findings, suggest tumor are either cases of tumor in which the biopsy bite was not sufficiently deep or else cases of inflammation mistaken for tumor.

In such cases as deep a bite as possible should be made and it is particularly recommended to repeat biopsy at the same site in order to ensure obtaining diagnostic material. This type of lesion is most commonly seen in adenocarcinoma (Figs. 109, 110) and large cell carcinoma.

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**Fig. 108** In performing biopsy in cases of extramuscular invasion deep bites or rebiopsy of the same site should be made.
Fig. 109 Biopsy specimen from the case shown in Fig. 139. Biopsy obtained material as deep as the extramuscular layer. Poorly differentiated adenocarcinoma appearing as rows of small tumor nests occupies the entire extramuscular layer. Lymphocyte invasion of the lamina propria and the smooth muscle layer can be seen but no tumor formation is recognized.

Fig. 110 Histologic findings of the upper division bronchus of the case shown in Fig. 135. Biopsy obtained material as deep as the extramuscular layer in which adenocarcinoma with irregular duct lumens and small tumor nests are recognized. Invasion of the smooth muscle layer can be recognized.
Lymph Duct Invasion

In specimens obtained from areas of redness or edema, widened bronchi or normally appearing areas surrounding tumors, occasionally proliferating tumors dilating lymph ducts can be observed (Fig. 111). If the lymph duct invasion is

Fig. 111 Successful biopsy of cases of lymph duct invasion is infrequent. Several biopsies should be made (see Fig. 108).

Fig. 112 Histologic findings of the case shown in Fig. 136. To determine the extent of tumor invasion, biopsies were performed at the bifurcations of the upper and lower division bronchi, B^6 and the lower lobe bronchus and at the carina. This specimen was from the bifurcation of B^6 and the lower lobe bronchus. Tumor cells were recognized in the lymph duct lumen of the lamina propria of mucosa that was considered normal endoscopically. Small clusters of sub-mucosal tumor cells cannot be recognized endoscopically.
extensive and the tumor proliferation is remarkable, the endoscopic findings generally suggest tumor, but if the number of cells is small it may be impossible to make a diagnosis on the basis of the endoscopic findings.

In some cases tumor cells have been recognized at one site in the lymph duct lumen in cases suspected of bronchitis. This type of finding is most commonly observed in adenocarcinoma (Fig. 112), particularly in cases of breast cancer metastatic to the lung.

Fiberoptic Bronchoscopic Criteria for the Diagnosis of Early Stage Squamous Cell Carcinoma

Central type (hilar type) early stage cancer is defined as a lesion confirmed to be limited to within the walls of bronchi as distal as segmental bronchi by histopathological examination of the resected specimen.95)

As greater understanding of the nature of early stage central type lung cancer is amassed through developments in fiberoptic bronchoscopy and the spread of sputum cytology surveys, increasing numbers of early stage squamous cell carcinoma are being detected. However there are also cases which, while they appear to be early stage cases to the clinician, confirmation by examination of the resected specimen is not possible because of inoperability or refusal of surgery. It is therefore necessary to have a diagnostic frame of reference to evaluate such cases as central type early stage cases. In gastrofiberscopy it is possible to clinically diagnose early stage gastric cancer preoperatively and on that basis to select therapeutic strategy, including surgical procedure. Of all the histologic types of lung cancer, central type early stage squamous cell carcinoma is probably the only one in which a diagnosis of early stage can be made on the basis of the bronchoscopic findings. It is also now understood that a 100% five-year survival is possible by surgical treatment of this group.80) Cure can also be obtained by non-surgical techniques, such as radiotherapy or laser photoradiation and it is likely that in the not-too-distant future it will be possible to select from among a variety of curative treatments.

The authors developed criteria for the endoscopic diagnosis of early stage central type squamous cell carcinoma, based on careful study and comparison of the endoscopic findings and the pathological findings of resected specimens. The clinical criteria and the endoscopic criteria that must be fulfilled in order to allow a diagnosis of early stage central type squamous cell carcinoma to be made are shown in Tables 5, 6 and Fig. 113.

Cancer that can be diagnosed on the basis of these criteria include the superficially invading type and nodular protrusions. These criteria are not used for evaluation of large nodular protrusions or polyps obstructing the bronchus.
Table 5  Clinical criteria for central type early stage lung cancer

1) Chest X-ray is negative or shows only secondary changes
2) A diagnosis of Stage I lung cancer has been made
3) The lesion is located from the main to subsegmental bronchi
4) Biopsy shows that invasion extends only up to the extramuscular layer

Table 6  Bronchoscopic diagnostic criteria for central type lung cancer

1) Mucosal irregularity or granulation
2) Obscurity, thickening or loss of mucosal folds
3) Disappearance or abrupt cut-off of mucosal surface vessels
4) Endobronchial protrusion or swelling
5) The peripheral margin of invasion can be recognized

Fig. 113  Findings in early stage central type lung cancer.
Fig. 114 A 68 year-old male heavy smoker presented with hoarseness, cough and bloody sputum, but the routine chest X-ray film revealed no abnormalities. Cytologic examination of sputum revealed class V squamous cell carcinoma. Endoscopy was performed on a suspicion of lung cancer, particularly early stage central type. A tumor located at the vocal cords was detected and biopsy revealed squamous cell carcinoma, but the findings were normal in the trachea and as far as subsegmental bronchi and selective washing of all lobar bronchi revealed only class I–II cells.
Fig. 115 A 62 year-old male, moderate smoker. Central type early stage, detected by chest X-ray and sputum cytology mass survey. In this chest X-ray negative, sputum cytology positive case, the lesion was limited to the area at the orifice of B^{1+2} delineated by arrows. Swelling was seen in this area, particularly in B^{1+2}a+b. There is also redness, which careful examination reveals to be due to the proliferation of extremely fine vessels. Biopsy yielded a diagnosis of early stage central type squamous cell carcinoma.

Fig. 116 A tumor with granular protrusions was recognized at the orifice of left B^{10} of a 65 year-old male. Mucosal epithelial invasion was recognized by the fine granular changes in the mucosa proximal to the tumor. The lateral wall of the bifurcation of B^{9} and B^{10} shows a loss of sharpness of the bifurcation and mucosal thickening can be seen, showing that the tumor has developed into B^{9}. The margin of squamous cell carcinoma lesions often ends with intraepithelial invasion, therefore care is necessary to evaluate the exact extent of the lesion. Biopsy suggested this case to be early stage squamous cell carcinoma limited to within the bronchial wall and the resected specimen revealed this to be so.
Fig. 117  A diagnosis of left pneumonia was made on the basis of the chest X-ray film of a 47 year-old male who presented complaining of fever and cough. In the process of detailed examinations squamous cell carcinoma was detected in right B². Right upper lobectomy was performed and serial sections from B² to the subsegmental bronchi were compared with the endoscopic findings. The mucosal epithelium of B² had been replaced by squamous cell carcinoma and intraepithelial invasion extended to the bifurcation of B¹ and B³ (arrows) where loss of luster and slight thickening was observed. Squamous cell carcinoma, diagnosed on the basis of biopsy materials.

Fig. 118  This case is the same as that shown in Fig. 117. Unevenness extends throughout B². The inferior wall of B² (lower left) is almost completely covered by superficial invasion, the anterior wall (upper portion) has superficial invasion and invasion as far as the extramuscular layer, as do the superior (right) and posterior (lower) walls. In part the elastic fiber bundles are exposed due to cancerous ulcer formation. Remarkable widening of the bifurcation of B²a and B²b, exposure of the lesion, invasion as far as the cartilage layer and in part invasion as far as the peribronchial tissue was recognized in the resected specimen. Proliferation of very fine vessels can also be recognized at this bifurcation.
Fig. 119 A 71 year-old male, chest X-ray negative, sputum cytology positive. This figure shows the left upper division bronchus and the arrows delineate the extent of superficial invasion of squamous cell carcinoma. The tumor grows exposed in the bronchial lumen. The border with the normal mucosa appears to be marked by an elevation caused by swelling. The mucosal folds have disappeared and proliferation of extremely fine neoplastic vessels can be recognized. The area of invasion extends from B^3 across the bifurcation of B^{1+2} in part. It also spreads along the anterior wall of B^3, but the distal margin of the invasion can be recognized endoscopically. Biopsy of the bifurcation of B^{1+2} and B^3 revealed this case to be an early stage squamous cell carcinoma, limited to within the extramucosal layer (see Fig. 105).

Fig. 120 A nodular protrusion was recognized at the bifurcation of right B^1 and B^2 in a 70 year-old male. B^1 was stenotic due to the protrusion, the surface of which was finely granular. Intraepithelial invasion from the tumor towards B^3 was recognized. Biopsy of the protrusion yielded a diagnosis of squamous cell carcinoma. This was an early stage case limited to within the bronchial wall.
Fig. 121 A small nodular protrusion can be seen at the bifurcation of B^{10}a and B^{10}b+c. The protrusion displayed small amounts of bleeding and vascular engorgement. From the fact that this lesion was not recognizable on chest X-ray film it was considered to be an early stage case with proliferation not extending to beyond the extramuscular layer. Although the longitudinal folds had disappeared the circular folds appeared clearly, which suggests hypertrophy of the smooth muscle. Squamous cell carcinoma was diagnosed by biopsy of the tumor.

Fig. 122 The surface of the tumor obstructing B^{1+2}a is covered with necrotic material. This tumor was considered to have originated in the periphery, developing in the bronchial lumen as a polypoid lesion. The bifurcation with B^{1+2}b shows widening and thickening due to invasion. No abnormal findings can be recognized in the bronchial wall around the tumor. Biopsy of the tumor revealed squamous cell carcinoma.
Fig. 123 The tumor obstructing the left upper division bronchus of a 62 year-old male is covered with necrotic material and degenerated mucus. The border between the tumor and the surrounding normal mucosa is clear and the bifurcation between the upper division bronchus and the lingular bronchus is sharp, suggesting the absence of invasion. The circular folds in the mucosa of the lingular bronchus can be seen, also suggesting the absence of invasion. Biopsy of the distal portion of the tumor revealed squamous cell carcinoma.

Fig. 124 The base of the tumor obstructing the left upper lobe bronchus in a 65 year-old male was located in the upper division bronchus and a slight opening to the lingular bronchus can be seen. The surface of the tumor is covered with engorged vessels. In the area surrounding the tumor, the redness on the side of the upper division bronchus is the result of obstructive pneumonia in the distal upper division. Biopsy yielded a diagnosis of squamous cell carcinoma.
Fig. 125 The middle lobe bronchus of a 68 year-old male is obstructed by a tumor covered with necrosis. Tumor invasion has involved the extramural lymph nodes forming a large submucosal tumor in the anterior wall of the lower lobe bronchus. In the truncus intermedius close to the middle lobe bronchus the longitudinal folds are accentuated (arrows) suggesting that in this area most of the invasion is in the extramuscular layer. The middle lobe bronchus in which the tumor can be seen shows extramural compression. Biopsy of the tumor in the middle lobe revealed squamous cell carcinoma.

Fig. 126 An irregular granular-surfaced tumor obstructs right B^9 + B^10 of a 56 year-old male. Stenosis of B^7 was caused by proximal compression by the tumor. No continuous invasion to surrounding bronchi from the tumor is recognized. The tumor developed from the distal area as a polyp. A diagnosis of squamous cell carcinoma was made by biopsy (see Fig. 103).
Fig. 127 These are the findings of the lower lobe bronchus in a case of squamous cell carcinoma arising in the lingular bronchus of a 62 year-old male. Invasion, occasionally breaking through the mucosa to appear exposed in the bronchial lumen, extends continuously to the anterior wall of the lower lobe bronchus from the metastatic interlobar bronchial lymph nodes between the lingular and lower lobes. The exposed areas are recognized by white mossy necrosis, and the longitudinal folds have disappeared. Biopsy of the tumor yielded a diagnosis of squamous cell carcinoma.

Fig. 128 The surface of the tumor obstructing the right basal bronchus of a 65 year-old male is covered with necrotic material and bleeding can be recognized. There is no invasion in the surrounding mucosa and the mucosal fields are clearly recognizable. The stenosis of B⁶ is due to compression from the tumor. Biopsy of the tumor yielded a diagnosis of squamous cell carcinoma.
Fig. 129 These are the findings in the left upper lobe of a 66 year-old male. The mucosal folds seen here are markedly different from the accentuated irregular folds commonly seen in adenocarcinoma. The resected specimen revealed that the tumor extended to involve the lingular and upper division extramural metastatic lymph nodes, thereby compressing the upper lobe bronchus. Usually the circular mucosal folds in the left upper lobe and lingular bronchus are clearly seen, therefore this kind of wrinkled appearance is probably due to an extrabronchial tumor. Squamous cell carcinoma was diagnosed by biopsy of the tumor.

Fig. 130 The surface of the bifurcation of \( B^{1+2} \) and \( B^3 \) is uneven, and widening of the bifurcation of the upper division and lingular bronchi of a 62 year-old male can be recognized. This case was roentgenologically occult lung cancer. The several reddish-brown spots represent neoplastic stroma and accompanying blood vessels, both of which accompanied neoplastic growth, at the bifurcation of the upper division and lingular bronchi. Histological examination of the resected specimen showed invasion to be limited to within the cartilage layer and no metastatic lymph nodes were observed, therefore this case was classified as an early stage central type lung cancer. A preoperative diagnosis of squamous cell carcinoma was established by biopsy.
Fig. 131 A nodular tumor obstructs the basal bronchus and vascular engorgement and necrotic materials can be seen on its surface. The tumor has invaded the truncus intermedius and the middle lobe bronchus, and the invading tumor can be seen to be exposed in the inferior wall of the middle lobe bronchus. The findings in the right wall of the middle lobe bronchus and in the truncus intermedius primarily suggest intramural invasion. Biopsy of the tumor obstructing the lower lobe bronchus revealed squamous cell carcinoma.

Fig. 132 The right upper lobe bronchus is stenotic and the middle lobe bronchus is obstructed by tumor. The tumor proliferates both intra- and extramurally and, in the areas in which it appears to be exposed, vascular engorgement and attachment of necrotic materials can be recognized. At the bifurcation of the upper lobe bronchus and the truncus intermedius the tumor is covered by the mucosal epithelium and in one area a network of fine neoplastic vessels can be seen. Biopsy yielded a diagnosis of squamous cell carcinoma.
Fig. 133 The truncus intermedius is obstructed by a tumor covered by necrotic materials in this 34 year-old male case who presented with cough and bloody sputum. The tumor proliferates intra- and extramurally. The bifurcation of the upper lobe bronchus and the truncus intermedius is remarkably widened due to invasion from the tumor. Submucosal invasion also extends along the anterior wall from the truncus intermedius to the main bronchus and proliferation of fine vascularization can be recognized. The longitudinal folds in the membranous portion of the main bronchus are thickened and slightly irregular due to invasion of the extramucosal layer. Biopsy of the tumor revealed squamous cell carcinoma.

Fig. 134 A granular surface due to the exposed tumor tissue and attached necrotic materials can be seen in this nodular lesion occupying the left main bronchus. The main bronchus is stenotic as far as the bifurcation of the lower and upper lobe bronchi due to the tumor which arises from the inferior posterior wall. Squamous cell carcinoma was diagnosed by biopsy.
Fig. 135 Pleural effusion-type lung cancer was detected in this 71 year-old male. Slight irregularity in the bronchial wall and fine accentuated irregular folds can be seen from the posterior portion of the left upper division bronchus (arrow) to B^{1+2}. These findings suggest submucosal invasion extending around the entire circumference of the upper division bronchus and that the majority of the lesion is primarily located in the extramuscular layer. Adenocarcinoma proliferating in the extramuscular layer was revealed by biopsy of the upper division bronchus (see Fig. 110).

Fig. 136 These are the findings in the same case shown in Fig. 135. Longitudinal folds can be seen all around the lower lobe bronchus. In the interest of caution, biopsy was performed the bifurcations of the upper and lower lobe bronchi, B^9 and the basal bronchus and in the basal bronchus. Lymph duct invasion was recognized in one part of the mucosal lamina propria in all specimens. In cases in which only a few cells infiltrate submucosally there is no macroscopically recognizable change in the structure of the bronchial wall and therefore such infiltration cannot be recognized on the basis of the fiberoptic bronchoscopic findings (see Fig. 112).
Fig. 137  No findings suggestive of tumor can be recognized from the left main bronchus. This case was adenocarcinoma originating in S$^{10}$. The roentgenological findings suggested metastasis to the left hilar and bilateral mediastinal lymph nodes. The longitudinal folds in the left lower lobe bronchus extending to the basal bronchus are widened and elevated, suggesting invasion of the smooth muscle layer. The resected specimen showed small numbers of malignant cells in the submucosal subepithelial lymph ducts, but this condition was not recognizable from the endoscopic findings.

Fig. 138  This is the basal bronchus of the case shown in the previous figure. Not only are B$^8$, B$^9$ and B$^{10}$ severely stenotic, their bifurcations are all blunted and widened due to submucosal invasion. The white area at the orifice of B$^8$ is the lesion breaking through the mucosa. The entire basal bronchus appears constricted as a result of invasion all around the bronchial wall in the smooth muscle layer.
Fig. 139 Right B⁰ and the basal bronchus show conical stenosis with distal obstruction. Longitudinal folds can be seen all around the bronchial wall continuing to the site of obstruction. These folds are not caused by elastic fiber bundles but are secondary changes as a result of much proliferation in the extramuralular layer all around the bronchial wall, causing a difference in the diameter of the superficial layer of the mucosa and of the smooth muscle layer. Circular folds can be seen in the middle lobe bronchus, but no endoscopic findings suggestive of invasion are recognized. Biopsy demonstrated adenocarcinoma proliferating in the extramuralular layer (see Fig. 109).

Fig. 140 Findings in the left upper division bronchus suggest tumor invasion all around the periphery, extending continuously around the bronchial wall. In the anterior wall, seen in the upper portion of this figure (arrow) thickened longitudinal folds and a glossy tumor suggest invasion of the mucosal lamina propria from the extramuralular layer. In the posterior wall (arrows) the folds show no abnormal changes, but there is a protrusion appearing to be the result of compression from beyond the bronchial wall (metastatic lymph node). At the bifurcation of B¹+² and B³ submucosal invasion is suggested. Biopsy of the tumor in B³ showed adenocarcinoma.
Fig. 141 The bifurcation of the upper lobe bronchus and the truncus intermedius of this 68 year-old female was widened due to metastasis of the interlobar lymph nodes. In the conically stenotic upper lobe bronchus accentuated irregular folds can be seen continuing from the main bronchus. Accentuated irregular folds can also be seen in the lateral wall of the truncus intermedius, with transition to smooth mucosa on the mediastinal side. Biopsy of the widened bifurcation revealed adenocarcinoma proliferating submucosally.

Fig. 142 These are the findings of the left bronchi in a 68 year-old case of adenocarcinoma originating in the right lung. The longitudinal and circular folds cannot be recognized up to the orifices of the segmental bronchi. Edema can be seen all around the bronchial wall with many engorged vessels. The longitudinal folds can be seen in the upper division bronchus and in the lower lobe bronchus, and the redness and edematous appearance subside gradually towards the periphery where the findings appear normal. Such findings are usually seen in carcinomatous lymphangitis. Biopsy of the bifurcation of the upper and lower lobe bronchi revealed adenocarcinoma proliferating under normal mucosal epithelium. Lymph duct invasion was recognized in places.
Fig. 143 The left upper lobe bronchus is almost obstructed by a submucosal tumor. Vascular proliferation can be seen in vessels between the tumor and the stretched mucosa. On the bronchial wall opposite from the tumor, proliferation and engorgement of vessels can be seen. The tumor is completely covered by mucosa. The circular folds in the inferior wall of the upper lobe bronchus remain intact, suggesting that invasion has not yet reached that site. Adenocarcinoma was diagnosed by biopsy.

Fig. 144 Poorly differentiated adenocarcinoma originated in right S3 in this 72 year-old male. In the right upper lobe bronchus only faint longitudinal folds can be recognized. Comparison with other segmental bronchi suggested that B1, B2 and B3 all showed a slight degree of stenosis. The existence of the normal structure of the lamina propria can be recognized. These findings are therefore considered to be due to extramural compression. Adenocarcinoma was diagnosed by TBLB of S3a and TBAB of the bifurcation of B1 and B2. A biopsy bite as far as the extramascular at the bifurcation of B1 and B2 failed to reveal tumor invasion.
Fig. 145  Purulent secretions were recognized in the depression at the orifice of the obstructed right upper lobe bronchus. Cancer invasion appears to extend to the wall of the bifurcation of the right upper lobe and the truncus intermedius from beyond the bronchial wall but is limited to the submucosal layer. In the main bronchus invasion is limited to the smooth muscle layer. Adenocarcinoma was diagnosed by biopsy of the bifurcation.

Fig. 146  A protruding polypoid lesion obstructs the right upper lobe bronchus of a 41 year-old male. The surface of the milky-white tumor is slightly irregular. No invasion in the membranous portion of the truncus intermedius is clearly recognizable. Atelectasis and elevation of the right middle lobe were recognized roentgenologically. Endoscopically, lateral elevation of the middle lobe bronchus was observed. Biopsy of the tumor revealed poorly differentiated adenocarcinoma proliferating below the mucosal epithelium.
Fig. 147 This case had received left upper lobectomy six years previously on a diagnosis of peripherally originating adenocarcinoma. A tumor can be seen protruding from the right wall of the trachea. The proximal margin of this metastatic adenocarcinoma proliferating beneath the mucosa is white and slightly irregular and in this area squamous cell metaplasia was recognized on the mucosal surface. Papillary adenocarcinoma was diagnosed by biopsy of the tumor.

Fig. 148 A lobulated glossy tumor can be seen in the center of the conically obstructed right upper lobe bronchus of a 68 year-old male. The longitudinal folds continuing from the right main bronchus up to the tumor show the effects of extramural compression as a result of metastatic hilar lymph nodes. The cartilage arches on the mediastinal side of the main bronchus are diminished. Biopsy of the tumor in the upper lobe bronchus revealed adenocarcinoma, covered by mucosal epithelium.
Fig. 149 The surface of the tumor in the left B₆ of this 49 year-old male was covered by necrotic material. No invasion to surrounding bronchi can be seen. The tumor obstructs B₆c and had developed from the periphery as a polyp. It is relatively rare for an adenocarcinoma tumor to be covered by necrosis and is probably due to the fact that this tumor had broken through the mucosa into the bronchial lumen. A diagnosis of poorly differentiated adenocarcinoma was obtained by biopsy.

Fig. 150 A tumor covered with necrosis is seen in the left main bronchus. Slight compression from beyond the wall on the mediastinal side can be seen. The redness and thick secretions in the left main bronchus are the result of obstructive pneumonia in the left lower lobe due to the tumor. The upper lobe bronchus can be seen in the distal portion of the left main bronchus. Biopsy of the protruding tumor yielded a diagnosis of squamous cell carcinoma, but the resected specimen revealed that the majority of the tumor was adenocarcinoma, with only the portion protruding into the left main bronchus showing differentiation to squamous cell carcinoma.
Small Cell Carcinoma (Figs. 151–158)

Fig. 151 A nodular tumor obstructs the right basal bronchus. The tumor is covered by the bronchial mucosa and appears glossy. Submucosal invasion can be seen at the bifurcations of the basal bronchus and B⁶, in B⁶ and the proximal side of B⁶ and the membranous portion of the truncus intermedius. In one area of B⁶ extramural invasion has broken through the mucosa and appears exposed in the lumen, accompanied by bleeding caused by suction. Stenosis of B⁶ is recognized. Biopsy yielded a diagnosis of oat cell type small cell carcinoma.

Fig. 152 A tumor can be observed in the right B¹b with coagula on its surface. The polypoid lesion appears to have originated from B¹b. The mucosa of the surrounding bronchial wall appears normal, with no evidence of invasion. Biopsy revealed oat cell type small cell carcinoma.
Fig. 153  A 57 year-old male. The tumor appears to invade from beyond the wall of the truncus intermedius, which it obstructs. The middle lobe bronchus is obstructed by the protrusion of the submucosal tumor. In the truncus intermedius the longitudinal folds are twisted and cut off. Vascular engorgement can be clearly observed in the area in which invasion involves the lamina propria. These findings are the result of continuous metastatic involvement of lymph nodes. Oat cell type small cell carcinoma was diagnosed by biopsy of the tumor (see Fig. 107).

Fig. 154  In the left main bronchus protrusions of varying size can be seen arising from continuous invasion by the primary tumor and from metastatic lymph nodes. The main bronchus is compressed due to intramural and extramural invasion and the lumen is remarkably stenotic. The stenosis of the upper lobe bronchus and lower lobe bronchus is so severe as to prevent insertion of the fiberoptic bronchoscope. The vascular network on the surface of the protrusions and the submucosal bleeding demonstrate the submucosal proliferation of the tumor. Histologic and cytologic diagnosis demonstrated intermediate cell type small cell carcinoma.
Fig. 155 The tumor obstructing the left lower lobe bronchus is accompanied by submucosal vascular proliferation. In one area the tumor breaks through the mucosa (arrow). The bifurcation of the left upper and lower lobe bronchus have become completely involved with the tumor and the bifurcation is remarkably widened. This intermediate cell type small cell carcinoma showed widespread submucosal invasion.

Fig. 156 The right main bronchus is obstructed due to intramural invasion and extramural invasion. Granular protrusions due to submucosal proliferation can be seen at the site of obstruction and in the membranous portion. The redness of the membranous portion shows the presence of submucosal invasion. The outline of cartilage has become unclear and fine vessels proliferate submucosally. These findings suggest subcarinal lymph node metastasis and invasion of the elastic fiber layer. Oat cell type small cell carcinoma was diagnosed by biopsy of the site of the obstruction.
Fig. 157 The truncus intermedius shows conical stenosis due to submucosal invasion extending around the entire periphery. Only a small aperture can be seen in the middle lobe bronchus and the basal bronchus. The longitudinal folds appear confluent and end due to compression where the tumor appears exposed. The bifurcation of the middle lobe bronchus and the basal bronchus is widened due to metastasis to the bifurcation lymph nodes and biopsy of this site yielded a diagnosis of oat cell type small cell carcinoma.

Fig. 158 A round polypoid tumor can be seen occupying the center of the trachea. This case was admitted complaining of severe respiratory distress. The tumor had a glossy surface and had developed as a polyp from the right wall of the trachea. Submucosal invasion could be recognized around the entire circumference of the trachea. Biopsy revealed a diagnosis of intermediate cell type small cell carcinoma. Such cases originating in the trachea are extremely rare.
Large Cell Carcinoma (Figs. 159–168)

Fig. 159 On the mediastinal side the cartilage rings have disappeared due to continuous invasion from extramural metastatic lymph nodes as far as the lamina propria. Also the longitudinal folds of the membranous portion of the truncus intermedius closest to the mediastinum have disappeared due to invasion of the lamina propria. Invasion in the lateral side of the truncus intermedius is limited to the extramural layer of the bronchus. In the area of invasion of the smooth muscle layer the musoca appears somewhat compressed and the longitudinal folds appear somewhat thickened and elevated. Large cell carcinoma, diagnosed by biopsy.

Fig. 160 These are the findings seen from the middle lobe bronchial bifurcation of the same case as shown in Fig. 159. The bifurcation of B₄ and B₅ is remarkably widened due to submucosal invasion. Invasion only as far as the smooth muscle layer can be seen in the posterior wall of the middle lobe bronchus which continues to B⁵ but in other areas invasion extends close to the mucosal epithelium. In particular the areas adjoining with the bifurcations of B₅a and B₅b and B⁴ and B⁵ show mucosal defects where the lesion appears exposed in the bronchial lumen. Also the longitudinal folds made of elastic fiber bundles show swelling and tension due to invasion of the extramuscular layer.
Fig. 161 In this 62 year-old male the circular folds have disappeared and slight irregularity can be seen in the anterior wall from the upper lobe bronchus to the upper division and lingular bronchus. The bifurcation of B^{1+2} and B^3 is thickened and stenosis due to compression as a result of submucosal invasion can be seen in both B^{1+2} and B^3. These findings suggest that invasion extends as far as the mucosal lamina propria. Compression of the anterior wall of the upper division bronchus appears to be the result of metastasis to lymph nodes. Biopsy of the bifurcation of B^{1+2} and B^3 revealed large cell carcinoma proliferating from the lamina propria to the extramucosal layer.

Fig. 162 The findings in the left basal bronchus reveal a tumor obstructing B^9. Necrosis can be seen on the tumor surface, the bifurcations of B^9 with B^8 and B^{10} are blunted due to invasion and B^8 and B^{10} are stenotic. The longitudinal folds in the basal bronchus appear constricted from beyond the bronchial wall and elevated, due to invasion of the extramucosal layer. Large cell carcinoma was diagnosed by biopsy of the tumor.
Fig. 163  The tumor is seen invading from beyond the bronchial wall of the right upper lobe bronchus. As a result of submucosal invasion the bifurcations of $B^1 + B^2$ and $B^3$ are thickened and widened. Invasion of the smooth muscle layer can be recognized in the anterior wall (upper portion of the figure), and in the superior wall (right side of figure). Also, due to thickening, the elastic fiber bundles appeared gathered and undulating, while the lumen is stenotic. In order to obtain diagnostic materials the biopsy bite of such areas should be deep, as far as the extramuscular layer. Large cell carcinoma was diagnosed by biopsy of the tumor.

Fig. 164  A tumor with protrusions varying in size can be seen extending from the middle lobe bronchus to the basal bronchus. In the lateral wall of the truncus intermedius, intramural and extramural invasion are seen to cause stenosis. Since the lesion is covered by the normal mucosa, thickened elevated folds, unrelated to the normal longitudinal folds, can be seen. Submucosal invasion extending longitudinally along the bronchus is the most likely interpretation. Such cases would not show changes on X-ray such as atelectasis or secondary changes due to infection. Biopsy of the orifice of the middle lobe bronchus revealed a diagnosis of large cell carcinoma.
Fig. 165  A tumor with verrucous protrusions can be seen in the lateral wall of the truncus intermedius. The widened bifurcation of the upper lobe bronchus and the truncus intermedius suggests continuous invasion to the bifurcation. The tumor invaded from beyond the bronchial wall to the extramuscular layer in the upper lobe bronchus and as far as the lamina propria in the truncus intermedius. No portion of the lesion was exposed in the bronchial lumen. Biopsy yielded a diagnosis of large cell carcinoma.

Fig. 166  The primary lesion of this large cell carcinoma case originating in left S₃ of a 58 year-old male was outside the examination range of the fiberoptic bronchoscope. A tumor with multiple nodules protrudes in the lateral wall of the left basal bronchus. The circular folds extend only half way around the circumference of the basal bronchus (arrow), indicating the extent of invasion. The tumor seen in this figure is the result of invasion from metastatic lymph nodes of the bifurcation of the upper and lower lobe bronchi. The bifurcation of B⁶ and the basal bronchus appears sharp but B⁶ appears compressed by pathological changes (lymph node metastasis) beyond the anterior wall. A diagnosis of giant cell subtype large cell carcinoma was obtained by biopsy of the tumor.
Fig. 167 A tumor covered by necrotic material projects from the right upper lobe bronchus. Granular tumor accompanied by submucosal bleeding can be seen near the membranous portion of the bifurcation of the upper lobe bronchus and truncus intermedius, which is widened due to invasion. However there appears to be no invasion of the membranous portion seen in this figure. Biopsy of the tumor was performed and a diagnosis of large cell carcinoma obtained.

Fig. 168 These are the findings in the case shown in the previous figure after removal of the necrotic material covering the surface of the tumor by means of biopsy forceps. The multiple nodular tumor obstructs the right upper lobe bronchus. The tumor appears to be completely exposed and not covered by mucosa, calling to mind the usual appearance of central type squamous cell carcinoma. Large cell carcinoma.
Other Pulmonary Tumors (Figs. 169–182)

Fig. 169 A grayish white tumor is seen in the middle lobe bronchus. A polypoid tumor is recognized in the bronchial lumen. Proximal to the bifurcation of the middle lobe bronchus, i.e. in the anterior wall of the truncus intermedius, the horseshoe cartilage folds cannot be recognized because of invasion and the surface is uneven. The lateral wall of the orifice of the middle lobe bronchus shows remarkable deformation as a result of extra- and intramural invasion. Biopsy revealed a diagnosis of carcinoid. Most cases of carcinoid are considered to originate in main or lobar bronchi, and the fact that this case originated distally with intramural invasion from metastatic lymph nodes suggested this was a relatively malignant case. Diagnosis was performed by biopsy.

Fig. 170 A tumor extends across the bifurcation of $B^1$ and $B^2$, both of which it obstructs. The tumor appears to extend submucosally to the bifurcation of $B^3$ and the upper lobe bronchus (right side of the figure). The tumor obstructing $B^1$ is covered by the mucosa, but that obstructing $B^2$ is completely exposed. Carcinoid was diagnosed by biopsy of the tumor.
OTHER PULMONARY TUMORS

Fig. 171 The truncus intermedius of a 68 year-old male was obstructed by a tumor proliferating submucosally. Vascular engorgement of vessels in the lamina propria was recognized. The resected specimen revealed that the tumor originated from the bifurcation of the basal and middle lobe bronchi. Biopsy yielded a diagnosis of adenoid cystic carcinoma.

Fig. 172 A tumor 8 cm in length occupied the center of the trachea causing severe respiratory distress. The multiple nodular tumor was vaporized by endoscopic Nd-YAG laser surgery to improve the patient’s condition. Subsequently resection and end-to-end anastomosis was performed. A diagnosis of adenoid cystic carcinoma was obtained by biopsy of the tumor. Most cases of adenoid cystic carcinoma occur in the trachea or main bronchi.
Fig. 173  Remarkable stenosis of the left main bronchus of an 11 year-old male was observed due to a tumor covered by a white mossy surface. No tumor invasion to the adjacent bronchial wall was recognized. Nd-YAG laser vaporization was performed and the tumor was recognized to have developed from the upper lobe bronchus as a polyp. Biopsy revealed mucoepidermoid carcinoma. Mucoepidermoid carcinoma generally develops in larger bronchi as far as segmental bronchi and usually is not completely covered by mucosa.

Fig. 174  A tumor with a glossy surface obstructs the right basal bronchus. No engorged vessels or necrotic materials can be seen on the surface of the tumor. There is only a slight space between the tumor and the surrounding bronchial wall, but no thickening of the longitudinal folds can be seen. There is no redness of the mucosa or viscous secretions and there is also no secondary obstructive pneumonia distal to the lesion. Biopsy yielded a diagnosis of mucoepidermoid carcinoma.
Fig. 175  A polypoid tumor with a glossy surface obstructs the truncus intermedius. The clots attached to the tumor are the result of a previous biopsy procedure. The tumor is covered by mucosa, appears homogeneous and engorged vessels cannot be seen on the surface. Also no invasion can be seen in the mucosa of the surrounding truncus intermedius. A definitive diagnosis could not be made on the basis of the biopsy specimen, but the resected specimen yielded a diagnosis of malignant hemangioendothelioma.

Fig. 176  A 46 year-old male with episodes of repeated pneumonia in the left upper lobe. A polypoid tumor with abundant blood vessels and an irregular rugged surface obstructs the left upper lobe bronchus. No pathological findings were observed in the surrounding bronchial wall. Although submucosal bleeding and red spots can be seen on the surface of the tumor, the latter were formed due to stroma and blood vessels both related to neoplastic growth in the submucosal layer. Biopsy yielded a diagnosis of oncocytoma (low grade malignant tumor, generally originating in the salivary gland).
Fig. 177 A 65 year-old male presented with a complaint of respiratory difficulty. Cytologic examination of sputum revealed melanoma cells, but no melanoma cells were obtained from the patient pleural effusion. The primary lesion in this case was malignant melanoma of the left thumb. The entire orifice of the basal bronchus was brown with a slightly irregular surface and submucosal invasion extended widely. Biopsy confirmed a diagnosis of melanoma metastatic to the bronchus.

Fig. 178 This case presented with cough and bloody sputum three years after surgery for cancer of the colon. Chest X-ray film revealed a nodular shadow in the left lower lung field. Fiberoptic bronchoscopy revealed obstruction of $B^8$ caused by a polypoid lesion, but there was no invasion to the walls of surrounding bronchi. The surface of the tumor was white and it was covered with necrotic material. Metastasis from the colonic cancer was confirmed by biopsy.
Fig. 179 This was a case of metastasis from esophageal carcinoma. The tracheal lumen is maintained due to the horseshoe shaped cartilage rings, but multiple proliferation of a granular tumor that bled easily was recognized from the superior portion of the carina to the carina. The vessels in the lamina propria show engorgement with occasional erosion and bleeding. Biopsy of the tracheal wall revealed squamous cell carcinoma. The lamina propria was totally replaced by tumor and in places and the exfoliation of the epithelium was recognized in some areas. The endoscopic findings were confirmed on autopsy.

Fig. 180 This case, which had undergone surgery for cancer of the esophagus five years previously, presented with respiratory distress. Recurrence of esophageal cancer in continuous invasion to the trachea was recognized. The trachea was stenotic but there were no symptoms suggestive of stenosis of the reconstructed esophagus. Because of the remarkable tracheal stenosis insertion of the fiberoptic bronchoscope was impossible.
Fig. 181 A tumor can be seen obstructing B₈a₁i. B₈a₁ is compressed from the direction of the mediastinum in a lateral direction. The surface of the tumor is glossy and is covered with viscous secretions. Since the circular folds in B₈a₁ and B₈a can be recognized it can be seen that there is no invasion in these areas. Biopsy revealed clear cell carcinoma. Since the patient had undergone left nephrectomy for renal cancer three years previously, this case was diagnosed as renal carcinoma metastatic to the lung.

Fig. 182 This 72 year-old female presented with dyspnea. An easily bleeding tumor was recognized almost obstructing the trachea immediately below the vocal cords. In the tracheal wall the cartilage ridges and the longitudinal folds of the membranous portion had disappeared while the tumor was observed to invade submucosally around the entire tracheal circumference. The base of the polyp in the trachea was in the membranous portion. Biopsy revealed papillary adenocarcinoma and a diagnosis of invasion to the trachea of thyroid adenocarcinoma was made.
Squamous Metaplasia (Figs. 183–188)

Fig. 183  A 54 year-old male presented with a complaint of cough persistent over several years, recurrent bloody sputum caused by the common cold. No bloody sputum was recognized when he presented. This figure shows the findings in the left upper division bronchus. The widened bifurcation of $B^{1+2}$ and $B^3$ shows irregularity, atrophy of the mucosa and the findings in general suggest cicatricial formation. Throughout a follow-up course of two years sputum cytology has revealed moderately to severely atypical squamous cell metaplasia.

Fig. 184  A 58 year-old female presented with a history of cough for a period of six months. Her chest X-ray was normal and she was a non-smoker. Results of sputum cytology were class III. Protrusions were recognized in the upper lobe bronchus immediately proximal to the orifice of $B^3$, the mucosa was irregular and there were also four small granular protrusions (arrows). Biopsy of this area yielded a diagnosis of squamous cell metaplasia.
Fig. 185 Sputum cytology was performed several times in a 55 year-old male case of persistent cough and repeated episodes of bloody sputum. Class IIIC cells and occasionally class IV cells were detected. The results of washing cytology, combined with those of fiberoptic bronchoscopy, suggested that the most suspicious site was the lateral wall of the right upper lobe bronchus. This site showed granulomatous irregularity resembling the superficial infiltrative type of squamous cell carcinoma, but it differed from the latter in that it had glossiness resembling that of cicatricial formation and was so hard that it was almost impossible to obtain a biopsy bite. Finally biopsy yielded a diagnosis of squamous cell metaplasia. During a follow-up course of three years class IV cells have occasionally been obtained by sputum cytology but the histologic diagnosis has consistently been squamous cell metaplasia.

Fig. 186 A 49 year-old female moderate smoker presented with a complaint of persistent cough. This figure shows the findings in the left lower lobe bronchus. The flattened orifice of B⁶ is stenotic due to cicatrix. The cicatricial findings and irregularity seen in B⁶ continue to the basal bronchus. Biopsy of the bifurcation of B⁶ and the basal bronchus yielded a diagnosis of squamous cell metaplasia.
Fig. 187 A general practitioner pointed out an abnormal shadow in the right middle lung field of a 64 year-old female who had presented with a cough of one month’s duration. However, when the patient was referred for more detailed examinations the abnormality on chest X-ray had disappeared. At bronchoscopy the trachea and both right and left main bronchi were seen to be covered all round by a mossy material which could not be removed by suction. When the mossy material was removed by repeated biopsies massive bleeding was recognized. Histologically, severely atypical squamous cell metaplasia was recognized.

Fig. 188 The carina of the same case shown in Fig. 187. The mucosa shows granular protrusions intermingled with mossy material. This was considered to be the result of reepithelization following ulcerative tracheobronchitis. After a two-week course of antibiotics remarkable decrease in the mucosal irregularity and the amount of mossy material was observed.
Inflammatory Diseases (Figs. 189–198)

Fig. 189 A 48 year-old male heavy smoker presented with a persistent cough. Sputum cytology revealed class II–III cells. The findings of the bifurcation of the left upper and lower lobe bronchi shown in this figure reveal widespread hyperemia and dilatation of the submucosal blood vessels. These findings are typical of chronic bronchitis. In this type of case submucosal bleeding is easily caused by cough.

Fig. 190 A smooth-surfaced tumor was recognized in the truncus intermedius of a 40 year-old male. He was referred to the authors' department with a diagnosis of adenoma, but biopsy yielded a diagnosis of granuloma due to non-specific inflammation. This tumor was vaporized by means of endoscopic Nd-YAG laser treatment.
Fig. 191 Ulceration, necrosis and granular tissue were observed from the central portion of the trachea extending past the carina to the truncus intermedius middle lobe bronchus, lower lobe bronchus. These tubercular findings differ from the findings in other diseases in that these findings appear almost isolated in the otherwise normal bronchial lumen and there is no redness, edema or vascular engorgements. The membranous portion of the trachea and the left main bronchus appear almost normal. Biopsy of the base of the ulcer revealed caseous necrosis and staining of the smear specimen revealed Gaffky 7, permitting a diagnosis of bronchial tuberculosis.

Fig. 192 This is the same case as shown in Fig. 191. Ulceration and necrotic tissue can be seen extending continuously from the trachea to the middle lobe bronchus, which is remarkably stenotic due to the necrotic material. No ulceration or necrosis was observed in the left bronchial tree, right B6 and the right upper lobe bronchus. The deepest extent of the tuberculous changes was as far as the cartilage and biopsy specimens revealed fragments of cartilage. Diagnosis of such cases can generally be performed easily by obtaining smear specimens as well as performing biopsy.
Fig. 193  Roentgenologically a lesion was recognized in the left upper lobe of a 31 year-old male but endoscopically cicatricial stenosis was observed in the left main bronchus. At the time of detection this case was Gaffky 2. After a one-year course of anti-tuberculosis drugs tests for tuberculosis bacilli were negative. However one year and six months later he complained of cough, sputum and wheezing. The lumen of the left main bronchus was remarkably stenotic due to membranous cicatricial formation and the cartilage arch appeared thinly tightened. The mucosal folds around the lesion were absent and glossiness was recognized. The membranous cicatricial lesion was vaporized by endoscopic Nd-YAG laser. He is now disease-free and living a normal life.

Fig. 194  These are the findings of cicatricial stenosis in the left basal bronchus proximal to the branching of the segmental bronchi in the same case shown in Fig. 193. The normal mucosal folds are absent and the surface is irregular, the basal bronchus is deformed with a bridging cicatrix causing stenosis as a result of contraction and leaving a small aperture connecting with B\textsuperscript{10}. In this case the lower lobe consisted largely of S\textsuperscript{6}, and B\textsuperscript{8}, B\textsuperscript{9} and B\textsuperscript{10} were remarkably ectatic due to secondary bronchiectasis.
Fig. 195 A cicatricial lesion to which the tracheal longitudinal folds appear to converge was seen in the center of the anterior tracheal wall of a 48 year-old male. This case had been complaining of dyspnea, particularly expiratory dyspnea, for a period of ten years. These are the findings of healed tubercular inflammation. On the left of this figure defects in three cartilage arches can be seen as a result of tuberculous inflammation, particularly the spread of ulcerative changes as far as the cartilage.

Fig. 196 In the same case shown in the previous figure, while a sufficiently large lumen was maintained during inspiration, on expiration the anterior wall of the trachea moved towards the membranous portion as can be seen here, and also the membranous portion slightly elevated. As a result remarkable tracheal stenosis occurred, causing expiratory dyspnea. This was a case of secondary tracheomalacia due to cartilage defect.
Fig. 197 Bronchitis due to aspergillus. This 52 year-old male had undergone left upper lobectomy due to pulmonary tuberculosis, followed by thoracoplasty. He visited his local physician due to the appearance of increasing cough and sputum. A granular protrusion was observed in the left lower lobe bronchus, covered by whitish mucosa and the lower lobe bronchus was obstructed by viscous material. Biopsy showed the granular tissue to be covered by squamous cell metaplasia. The viscous material was aspergilloma (Courtesy of Drs. Kei Hagiwara and Masamitsu Nogawa of Tokyo Metropolitan Government Cancer Detection Center, Tokyo).

Fig. 198 American blastomycosis. The symptoms of pulmonary blastomycosis include cough, chest pain, hemoptysis and fever. This case complained of hemoptysis and cough. Here necrotic material can be seen adhering to the lateral wall of the left main bronchus and the mucosa is edematous and the outline of cartilage is unclear (Courtesy of Dr. T. Akiba, São Paulo, Brazil).
Sarcoidosis (Figs. 199–206)

Fig. 199  A 24 year-old male presenting with a cough underwent chest X-ray and was referred to the authors' institution after bilateral hilar tumor shadows were detected. The type of protrusions shown in this figure were observed to extend from the trachea to all segmental bronchi bilaterally accompanied by engorgement of small blood vessels and remarkable thickening of the mucosa. The bifurcations of all lobar and segmental bronchi were remarkably widened and the lumens exhibited remarkable stenosis. One of the protrusions shown here was biopsied and a diagnosis of sarcoidosis obtained. Furthermore TBLB of the lung distal to left B³a, B⁵a, B¹⁰c and right B¹a and B⁹a yielded a histological diagnosis of sarcoidosis although chest film did not indicate any abnormal findings at those sites.

Fig. 200  These are the findings of left B⁶ of the case shown in Fig. 199. Small protrusions or nodules can be seen throughout the entire extent and thus the bifurcation of the subsegmental bronchi are not sharp but are irregular and slightly stenotic. While nodules cannot be clearly discerned in the subsegmental bronchi, the bifurcation is slightly edematous.
Fig. 201 A 24-year-old male presented with cough and exertional dyspnea. Redness was seen throughout the bronchus and there was proliferation and engorgement of vessels. Plaque in several areas, surface irregularity and remarkable stenosis were noted. This figure shows the right middle lobe bronchus, in which stenosis due to extramural compression and areas of plaque are seen. Fusion of the areas of plaque causes unevenness, and thickening due to edema is also remarkable. These pathological changes are typical of sarcoid lesions. Chest X-ray film revealed bilateral hilar lymphadenopathy (BHL) and the angiotensin converting enzyme (ACE) level was 74U.

Fig. 202 In the same case shown in the previous figure, symptoms improved remarkably after administration of 2,280 mg prednisolone over a period of two months and the BHL disappeared. The ACE level decreased to 22U. Plaque disappeared, the irregularity in the mucosal surface improved and the circular folds in the mucosa became clearly recognizable. B⁴ and B⁵ and all subsegmental bronchi could be examined.
Fig. 203 A 24 year-old male presented with cough, sputum and chest pain. Chest X-ray revealed BHL with an infiltrative shadow surrounding it. The ACE value was 120U. The characteristic plaque of sarcoidosis, remarkable bronchial stenosis and irregularity throughout the bronchus was seen. This case also had extremely marked vascular changes. The proliferation of vessels appeared to form a crazy-paving pattern. These vessels were judged to be neoplastic vessels arising from the bronchial artery and supplying the sarcoid lesions.

Fig. 204 The findings after treatment of the case shown in the previous figure. Over a period of two months 2,400 mg prednisolone was administered with resulting loss of symptoms, disappearance of BHL and decrease in ACE to 24U. The stenosis due to extramural compression decreased in accordance with the disappearance of BHL. This figure shows the improvement of the previously widened bifurcation of the right upper lobe and the truncus intermedius. However the pathological vascular changes still remain to some extent.
Fig. 205 The truncus intermedius of a case of sarcoidosis. Compression in the left and right lateral walls due to swollen lymph nodes has resulted in remarkable stenosis. Much plaque can be seen and protruding granulomatous lesions are observed bridging the bronchial lumen.

Fig. 206 The vascular findings of an area of plaque as seen through a fiberoptic bronchoscope with 20x magnification. When viewed through a conventional fiberoptic bronchoscope this area would appear granular with scanty vascularization, but the magnified view reveals the proliferation and engorgement of neoplastic vessels from the bronchial artery. Many investigators have reported on the characteristic vascular findings of sarcoidosis, but as yet the relationship between this aspect of the disease and BHL has not been clarified.
Fig. 207 A 23 year-old male case of tetralogy of Fallot had undergone Blalock-Taussig operation at age five. One year previously stenosis of the pulmonary artery had developed and his hypoxic condition increased, with the appearance of cyanosis. On admission his PaO₂ was 35 torr, PaCO₂ was 27 torr and his oxygen saturation was 70 %. Remarkable mucosal vascular engorgement was seen throughout the airway, including the oral lumen and larynx. This figure shows the bifurcation of the right upper lobe and truncus intermedius. Swollen irregular vessels are recognized below the mucosal surface. The vessels appear dark brown or dark reddish-purple, suggesting the flow of large amounts of hypoxic blood.

Fig. 208 This is the right middle lobe bronchus of the case shown in Fig. 207. The vascular engorgement was seen throughout the bronchial tree as far as could be examined by the fiberoptic bronchoscope, i.e. as far as subsubsegmental bronchi. The submucosal vessels are darkly purple in color. It has been reported that in cases of congenital heart diseases the bronchial artery is usually well developed. On the other hand in cases of acquired heart diseases the bronchial vein is said to be well developed.
Fig. 209 This is the left upper lobe bronchus of the same case shown in Fig. 207. The results of cardiac catheterization revealed the right arterial pressure to be 10/2 mmHg, right ventricular pressure to be 140/0 mmHg, and aorta pressure to be 140/96 mmHg. On scintiscanning the pulmonary artery and aorta were visualized simultaneously due to a right-left shunt. The lack of pulsation of these highly developed and engorged vessels was remarkable. The branch-like spread of the vessels here is unlike the longitudinally extending vessels observed in cases of acquired heart diseases. The vessels seen here are the distended bronchial artery but the color is dark reddish-purple because of the hypoxic arterial blood.

Bronchial Venous Varix (Fig. 210)

Fig. 210 This 63 year-old female case had experienced occasional episodes of bloody sputum over the previous few years but no abnormality was recognized on chest X-ray and she appeared to have no cardiac abnormality. A dark purple vessel was recognized in the anterior and left wall of the trachea where it appeared as a non-pulsating cystic dilatation. Fine capillaries were seen on the surface of the vessel. No other abnormalities were seen throughout the tracheobronchial tree. From the color of the blood vessel it was considered to be related to the bronchial vein and this case was considered to be a rare case of bronchial venous varix.
Fig. 211 A 19 year-old male lost consciousness during a fire that broke out while he was heavily intoxicated, but was rescued by a friend. Airway burn was suspected because of the high temperature of the room and the smoke. On admission the values of PaO$_2$ and PaCO$_2$ breathing room air were 67 and 31 torr, respectively. Fiberoptic bronchoscopy was performed seven hours after he received the burn. The vocal cords were covered with soot and were swollen and flaccid due to edema.

Fig. 212 These are the findings of the case shown in Fig. 211 three days later. Although almost all the soot has disappeared white areas of necrosis and edematous swelling can be seen. The flaccidity of the vocal cords remains unchanged.
Fig. 213  Findings of the carina in the same case shown in Fig. 211, seven hours after receiving the burn. In areas that are not covered with soot mucosal redness and swelling can be seen. These are classical findings of airway burn.

Fig. 214  These are the findings of the same area shown in Fig. 211, three days after the patient was burned. From the third to the sixth day eschar, erosion, bleeding, increased secretions, exfoliated necrotic material in mucus and heavily viscous secretions appear, depending on the degree of the depth of burns. The most effective method of treatment during this stage is repeated insertion of the fiberoptic bronchoscope for suction procedures, i.e. bronchial toilet.
Fig. 215 The left main bronchus of the same cases shown in Fig. 211. White necrotic areas, increased secretion and soot can be seen. Soot was seen in various segmental and subsegmental bronchi.

Fig. 216 The findings of the same case shown in Fig. 211, three days after the patient was burned. Increase of secretions, areas of erosion and remarkable redness, bleeding and mucosal edema can be seen.
Fiberoptic bronchoscopy should be performed in all cases of facial burns in order to examine whether airway burn is present, and if so, to what extent. Changes in the appearance with time such as redness, edema, easy bleeding, secretions and exfoliation of necrotic scabs are remarkable.

Fig. 217 Findings in a case of mild airway burn accompanied by facial burns. Black soot can be seen adhering to the upper division bronchus and orifice of the lower lobe bronchus. The longitudinal folds in the main bronchus (right half of this figure) are slightly emphasized as a result of the mucosal and submucosal swelling and appear greyish-white. These are the usual findings of mild airway burn. Since airway burn can occur even in cases unaccompanied by facial burns fiberoptic bronchoscopy should be performed in all suspicious cases.

Fig. 218 A case of facial burns received in a fire. Cases of second degree facial burns complaining of respiratory disturbance are extremely common. Adhering black soot can be seen. In this case the areas of greatest adhesion of soot were the bifurcation, which also showed whitening and edema due to the burns. Changes in the appearance with time such as redness, edema, easy bleeding, secretions and exfoliation of necrotic scabs are remarkable.
Airway Foreign Bodies (Figs. 219–226)

Choice of the rigid bronchoscope or the flexible fiberoptic bronchoscope is a case-by-case decision, depending on the skill of the operator and the conditions of the health facility, therefore it is impossible to make a blanket statement concerning this point. In the future the potential of the fiberoptic bronchoscope in the removal of foreign bodies will increase even more and this technique should become increasingly widespread. For this the development of a wider range of extraction forceps is necessary.

Fig. 219 A 13 year-old male climbed on a stand with a thumbtack in his mouth to hang up a poster. At the instant the stand wobbled he inhaled it into his trachea. The pin is in the center of the trachea and the tip is embedded in the membranous portion pointing in an oral direction.

Fig. 220 In the same case shown in the previous figure the middle of the thumbtack was grasped by forceps and pressed gently in a distal direction to extract the tip from the membranous portion then the tip was grasped by the forceps and it was slowly drawn out.
Fig. 221 A gold dental crown is seen here in the left basal bronchus. The circular mucosal folds exhibit slight redness on the mediastinal side. The crown was extracted by means of non-slip rubber-tipped forceps. This type of foreign body can be readily extracted under local anesthesia using the fiberoptic bronchoscope.

Fig. 222 Lung cancer was suspected in this case which presented with cough, bloody sputum and in which chest X-ray revealed atelectasis of the right middle and lower lobes. A false tooth broken in two was recognized in the truncus intermedius and B6, surrounded by granulomatous tissue. The patient had no recollection of such an event. Routine biopsy forceps (FB-19C) were employed to remove the parts of the tooth and the granulomatous tissue. The atelectasis disappeared.
Fig. 223  A man inhaled a double-tipped wall staple he had in his mouth while working and it was found in the right main bronchus with the center portion pointing towards the back and both the tips pointing in an oral direction. The trachea and bronchi showed no damage whatsoever. As direct removal would probably cause damage, the pin was first grasped by the center part covered in vinyl by biopsy forceps and brought to the carina where it was rotated by a curette used for cytologic examination so that the tips pointed towards the right and left main bronchi. It was then removed by biopsy forceps.

Fig. 224  This case accidentally inhaled a decayed tooth. Because of the sharp edge of the tooth and its movement due to violent coughing, the bronchial mucosa was damaged and he complained of bloody sputum. The tooth was removed with routine biopsy forceps (FB-19C).
Fig. 225 A seven-year old boy was playing with the cap of a ball point pen by suctioning it onto the tip of his tongue when he accidentally inhaled it. After two weeks of cough and bloody sputum he developed fever. This figure shows the findings 17 days after inhalation. The left main bronchus shows redness and is slightly stenotic due to edema. The bifurcation of the upper and lower lobe bronchi is widened and multiple granulomas are seen due to the stimulation by the foreign body. Heavily viscous secretions prevented almost all ventilation in the left lung. These findings show the appearance after suction of the secretions and removal of the granulomatous tissue, whereupon part of the foreign body could be seen.

Fig. 226 The same case shown in the previous figure. The granulomatous tissue was removed little-by-little using biopsy forceps, then the foreign body was grasped by the forceps and removed. Bronchial foreign bodies can become covered by granular tissue in 10–14 days, making it impossible to recognize their location, therefore they should be removed as soon as possible after inhalation. In cases such as this one, in which a considerable amount of time has elapsed, granulomatous tissue should be removed gradually, taking care to avoid damage to the normal bronchial wall, until the foreign body becomes exposed, after which it can be removed.
Applications of Fiberoptic Bronchoscopy

The flexibility and functionality of the fiberoptic bronchoscope together with the simplified anesthesia and insertion method have significantly extended the indications and applications of bronchoscopy.

Diagnostic Procedures with the Fiberoptic Bronchoscope

Diagnosis in Diseases Involving the Bronchus

The overwhelming majority of procedures using the fiberoptic bronchoscope are performed for visual diagnosis, biopsy of abnormal changes or to obtain washings of the lesion for cytological, histological or bacteriological diagnosis. In cases of malignant tumors fiberoptic bronchoscopy, in conjunction with chest X-ray, is an indispensable tool in selecting the most appropriate therapeutic modalities on the bases of estimation of the stage, extent of tumor in the bronchus and diagnosis of histological type. In cases of inflammatory disease, fiberoptic bronchoscopy is also invaluable in recognizing the bronchi involved, the pathogenic bacilli and the most effective therapeutic agents by making sensitivity tests.

Bronchography

Bronchography can be an important examination method in order to grasp the exact nature of pulmonary diseases and in certain cases can yield information unattainable by endoscopy alone.

When the fiberoptic bronchoscope is used for bronchography or to obtain histologic or cytologic specimens from peripheral lesions under X-ray fluoroscopy, the X-rays naturally affect the glass fibers of the instrument. Kato reported that the amount of irradiation received by a fiberscope inserted into a subsegmental bronchus under X-ray fluoroscopy for 15 minutes amounted to 5 Rad. He also noted that a decrease in the amount of light transmitted began, commencing from a dose level of 5 Rad., while changes in the color of the glass
fiber bundle began with a dose level of 25 Rad., progressing through increasing degrees of yellowishness to dark brown. Furthermore he noted that for any given total radiation dosage, the change in color of the glass fiber bundle when the dosage was administered in fractions was less than when it was administered in a single session, and that while color change and decrease in brightness became more marked from a dosage of around 300 Rad., some recovery of color and brightness is obtained if the fiberscope is maintained protected from radiation53).

Kato also suggested that if the maximum time of exposure of the fiberscope to X-ray fluorography be 15 min (i.e. 5 Rad.) per day complete recovery will be obtained. In institutions in which fiberoptic bronchoscopes are used in combination with X-ray fluorography, it is recommended that one or more, if possible, be kept specially for use in such procedures.

**Instillation of Contrast Medium** While it is possible to perform this method using a Nelaton's catheter, Metras' catheter or a selective bronchial catheter, the authors perform all procedures using a fiberoptic bronchoscope (BF-B3R). The advantages of this method are the opportunity to examine the bronchus before instillation of the contrast medium, while aspirating secretions or instilling anesthetic agents through the instrumentation channel to ensure effective anesthesia. It is also significantly easier to perform selective instillation of contrast medium than when using other catheters. Above all, the advantages of this method are that it is simple, obtains good results and minimizes patient discomfort. The authors generally employ water-soluble Dionosil as it has few side effects, such as bronchial pneumonia, provides a clear image and it is easy to clean the instrumentation channel after use.

In order to instill the contrast medium without allowing it to enter the alveoli, instillation should be performed under X-ray fluorographic supervision. The contrast medium is instilled in 2—3 ml units in accordance with the beginning of inspiration of the patient. To visualize the entire left bronchus, first the tip of the fiberoptic bronchoscope is inserted to the bifurcation of the upper and lower lobe bronchi and 2—3 ml of contrast medium is instilled for orientation. Thereafter contrast medium is instilled into the basal bronchus and its segmental bronchi, followed by B6, the upper lobe bronchus and the segmental bronchi of the upper lobe. In the right lung, first the contrast medium is instilled into the truncus intermedius followed by the basal bronchus, middle lobe bronchus, B6 and the segmental bronchi of the upper lobe. If the image of a particular segmental bronchus is desired, the tip of the fiberscope is inserted and wedged into that bronchus and contrast medium is instilled gently, taking care to avoid too much pressure in order to prevent an image of the pulmonary alveoli.

After the procedure the contrast medium is removed by aspiration via the fiberoptic bronchoscope.
Obtaining Specimens for Histologic and Cytologic Diagnosis

The fiberoptic bronchoscope has come to occupy an essential role in the establishment of a definitive diagnosis of pulmonary diseases. Figure 227 shows the various approaches made with the fiberoptic bronchoscope to obtain material for histologic or cytologic diagnosis. In our institution the fiberoptic bronchoscope is involved in the diagnosis of 95% of all pulmonary diseases.

Fig. 227 Diagnostic applications of the fiberoptic bronchoscope.

1. Observation of pathological changes
2. Biopsy under direct observation
3. Cytology harvesting under direct observation
4. Transbronchial lung biopsy under X-ray TV monitoring
5. Peripheral cytology brushing under X-ray TV monitoring
6. Transbronchial aspiration cytologic and histologic harvesting under X-ray TV brushing
7. Bronchial lavage (for cytologic, bacteriologic and biochemical tests)
8. Selective bronchography under X-ray TV monitoring
When this technique was first developed, it was employed using a Metras’ catheter or the Tsuboi catheter. However now the fiberoptic bronchoscope is used, one reason being that it allows confirmation of the accurate selective insertion of the brush into subsegmental or subsubsegmental bronchi.

The authors began using the fiberoptic bronchoscope for this procedure in 1970. Some bronchoscopists are reluctant to employ it in such procedures because of the discoloring effect of X-rays on the glass fibers, as mentioned above. We keep a fiberoptic bronchoscope specially for these procedures performed under X-ray.

Before the procedure, tomograms and bronchograms are examined carefully to understand exactly what bronchus is most closely related to the lesion. Since the brush or curette might not be able to be inserted through the instrumentation channel after the fiberoptic bronchoscope has been inserted to the target subsegmental or subsubsegmental bronchus because of the configuration of the instrument, the brush or curette is inserted and projected slightly from the tip of the fiberoptic bronchoscope when it has reached the main bronchus or lobar bronchus.

Brushing of peripheral lesions is effective in cases of lung cancer, tuberculosis, hamartoma and sclerosing hemangioma. In particular, adenocarcinoma frequently involves two or more segmental bronchi, therefore in cases suspicious of adenocarcinoma examination is not limited to one subsegmental bronchus. Also, in cases suspicious of tuberculosis a specimen is always prepared for examination for tubercle bacilli.

During the examination, contact between the brush and the lesion must be confirmed by fluorographic monitoring from a variety of angles. X-ray films should be taken from various angles for thorough postprocedural evaluation. The procedure is most easily performed in cases in which the site of the lesion requires a minimum of angulation of the fiberoptic bronchoscope. The most difficult sites in which to perform this method are those subsegmental bronchi in both upper lobes that distribute toward the direction of the mediastinum, i.e. in left B1+2a,b, and B2b,c and in right B1a,b, B2a and B3b, but success is usually obtained with a double-jointed brush or curette. In the not-so-distant past when the fiberoptic bronchoscope was first introduced it was employed only in the diagnosis of central type lung cancer, but at present, with the development of the present method and TBLB described below, it is now indispensable in the diagnosis of peripheral lung cancer and has become a most effective weapon in the attempt to obtain definitive diagnosis of pulmonary diseases.

The rate of diagnostic accuracy by this method in cases of peripheral type lung cancer is 75%—97%. In the 10-year period from 1974 to 1983 the rate of diagnostic accuracy of this method at Tokyo Medical College was 91%. Apart from slight bleeding that halts spontaneously, this method generally does not involve complications. The occurrence of serious complications is extremely rare.
Fig. 228 A 54 year-old male case with a cigarette index of 680 with cough, bloody sputum and fever was diagnosed as pneumonia of the right upper lobe and received a course of antibiotics. His symptoms disappeared and the abnormal shadow on X-ray reduced significantly. However a small lesion remained (arrow). After bronchography TBLB and brushing were performed and adenocarcinoma was diagnosed.

Fig. 229 The white arrow indicates B^2_{bii} at the same site as the infiltrative shadow seen in Fig. 228 and which converges towards the lesion. The black arrow shows B^3_{ai} drawn towards B^2_{bii}. 

Fig. 230 These figures show the lesion approached by a biopsy brush (BC-10C) and curette (CC-3C). The resected specimen revealed a 2 cm round tumor. The histologic type was well-differentiated papillary adenocarcinoma.

Fig. 231 From this figure it can only be seen that the cytology brush is inserted in B²b. However as insertion was made it was confirmed that it was being inserted in B²bii, after which the tip of the brush was guided to the lesion under X-ray monitoring. No abnormal findings can be seen in the bronchial wall in this figure.
BRUSHING OF PERIPHERAL LESIONS

Fig. 232 Fresh adenocarcinoma cells obtained by the brushing procedure shown in the previous figure. In comparison to sputum specimens the nuclear border is thin and the chromatin is finely granular.

Transbronchial Lung Biopsy (TBLB) (Figs. 233–242) There are many cases of pulmonary diseases in which the chest X-ray reveals diffuse or disseminated shadows. A variety of methods to obtain tissue from the lung for histologic diagnosis have been developed in the past, such as open chest lung biopsy, percutaneous needle biopsy and transbronchial lung biopsy. However the main criteria in performing histologic lung biopsy are to obtain sufficient material to allow a diagnosis, to obtain the material from the desired site, and for the method to be safe. Open chest lung biopsy meets the first two criteria but the degree of invasiveness is too high for it to be performed in all cases in which a definitive histologic diagnosis is necessary. TBLB has become established as a diagnostic method because it not only satisfies the first two criteria, but also has the advantage of being safe and able to be repeated, thereby permitting follow-up evaluation of therapeutic effectiveness.

TBLB is now an essential method for the diagnosis of cases appearing as a diffuse shadow on chest X-ray film. The authors employ this method not only for diffuse or disseminated shadows but also for the type of nodular shadows shown in Fig. 233.

As is shown in Fig. 233, the FB-19C forceps are inserted through the BF-B3R and brought to the lesion under X-ray television guidance to obtain tissue from it. This method involves making the forceps penetrate the bronchial wall to obtain tissue from beyond the bronchial wall. On inspiration the closed forceps are advanced into the lesion, then opened and closed on expiration, slightly twisting the forceps as they are retracted.

In general TBLB is a safe procedure. However it must be remembered that it is not indicated in all cases of solitary peripheral lesions. There are limitations to the
indications, depending on the anatomical site of the lesion and the angulation potential of the forceps. This is reflected in lower rates of diagnostic accuracy for cases of lesions located in the right S1, S3, S6 and left S1+2, S3 and S6 than lesions located in other pulmonary segments. In cases in which the forceps have to describe a relatively large angle to reach the lesion a double-jointed curette or brush, the tip of which can be angulated, should be used.

Diffuse pulmonary lesions are a good indication for this procedure. Usually the closed forceps are advanced to immediately below the pleura, then retracted for 1—2 cm after which they are opened, the patient is instructed to take and hold a deep breath then the forceps are closed and retracted while slowly twisting. In addition to biopsy of the most obvious target sites, biopsy is also performed in areas of less marked roentgenologically abnormal findings. Generally one TBLB procedure involves biopsy of 3—4 sites. In cases suspected of sarcoidosis, biopsy of areas in which no roentgenological abnormality is recognized can yield specimens of sarcoid lesions.

Since the specimens from the lung parenchyma are crushed they should be expanded by injection of 10% formalin prior to fixation.

Various investigators have reported the rate of complications of this procedure as 5-15%, including mortality due to bleeding. As has been indicated by Herf et al.42,48) coagulopathy is a contraindication for this procedure, therefore tests including bleeding time, coagulation time, prothrombin time, partial prothrombin time and platelet count are necessary before TBLB. In cases of severe dyspnea it is necessary to have adequate emergency treatment facilities available if TBLB is to be performed.

The rate of complications at the authors' institution is about 6%, i.e. pneumothorax 5% and hemoptysis 1%. All of these were mild and no case required hospitalization. Chest X-ray film or fluorography should be performed immediately after the procedure to detect pneumothorax. Half of the cases of pneumothorax healed spontaneously and the remainder were treated successfully by aspiration by a syringe or a Heimlich valve. Since the incidence of pneumothorax in TBLB increases with age, in elderly cases in which the chest roentgenogram suggests the possibility of pulmonary emphysema, care to avoid biopsy immediately below the pleura will contribute to decreasing the rate of complications.

In almost all cases of postprocedural bloody sputum or hemoptysis, evidence of bleeding halted within three hours at the latest. The authors have experienced no case of more than 50 ml bleeding, but Herf et al.42), in a questionnaire survey of 5,450 cases, reported 68 cases (1.2%) of more than 50 ml bleeding, and Hanson et al.32) reported three such cases out of 164 (1.8%). Furthermore Herf et al.42) reported 13 fatalities out of the 5,450 cases (0.24%) most of which were due to bleeding, in which the underlying disease was leukemia, malignant reticuloendothelial tumors, liver cirrhosis and diabetes. Therefore it appears that in cases of such underlying diseases even limited bronchopulmonary damage can lead to massive bleeding52). Other cases which should be considered as contraindications for TBLB are those receiving immunosuppressive treatment, cases of uremia and
other cases with a tendency to bleed. The great variation in the rate of complications reported by different investigators is probably partly due to the difference in cases examined.

The authors treat cases of bleeding as follows. If the forceps removed after TBLB reveal traces of bleeding, the fiberscope, which has been maintained in place, is then wedged into the subsegmental or subsubsegmental bronchus from which the bleeding is recognized and aspiration is performed. If bleeding is observed to seep around the tip of the fiberoptic bronchoscope, the patient is laid on his or her side so that the bleeding side is underneath, in order to prevent aspiration of blood by the contralateral lung. In cases in which bleeding is observed after a period of no bleeding, or in cases of relatively large amounts of bleeding, the patient is laid on the bleeding side and the fiberoptic bronchoscope is inserted to the main bronchus of the bleeding side and suction is performed. When the amount of bleeding decreases, the tip of the bronchoscope is advanced and wedged in the bleeding subsegmental or subsubsegmental bronchus. Bleeding generally halts within about three minutes. Hemostasis can be performed successfully in all cases without coagulopathy.

Other contraindications of this method include leukemia, pernicious anemia and other hemopathic diseases, renal insufficiency and pulmonary hypertension, strong cough reflex, pulmonary arterovenous fistula, pulmonary aneurysm, hemangioma, cardiac insufficiency, serious arrhythmia, during asthmatic attacks or immediately after myocardial infarct.

Since the specimens obtained by this method are relatively small, in cases with no histologic characteristics (such as diffuse panbronchiolitis) diagnosis is impossible unless relatively large specimens are obtained from several sites. This is a limitation of this procedure.

The rate of diagnostic accuracy of this procedure is 60—80%. Since interstitial pulmonary diseases have meager histologic characteristics, diagnosis is not always easy. Because the only other method that will yield significant information is open lung biopsy, there are many cases that must be evaluated on the basis of the information yielded by specimens obtained by TBLB and clinical data.

Definitive diagnosis by TBLB is possible in cases showing diffuse disseminated shadows roentgenologically, such as bronchioloalveolar cell carcinoma and carcinomatous lymphangitis metastatic from thyroid cancer or breast cancer. This method has also become used in many institutions recently for the diagnosis of nodular lesions.

Diagnosis of infectious pulmonary diseases is fairly simple if inclusion bodies or findings of interstitial pneumonia are recognized. Tuberculosis can be diagnosed on the basis of the presence of caseous granuloma, but the diagnostic rate accuracy is further enhanced by staining for tuberculosis bacilli. In particular, when malignant findings are not obtained by TBLB in cases of nodular shadows, it is necessary to obtain proof of another disease before the possibility of lung cancer can be ruled out. If no other diagnostic method yields results in such cases open lung biopsy is indicated. In other words a histologic diagnosis is necessary for a definitive diagnosis of lung cancer. This emphasizes the importance of the
transbronchial harvesting of tissue from pulmonary lesions for histologic diagnosis.

The diagnostic rate can be improved by cytologic diagnosis of a pooled three-day early morning sputum specimen after brushing or TBLB of a peripheral lesion.

Fig. 233 Biopsy forceps (FB-19C) are inserted into the shadow in the distal portion of B^2bii. Here the cups are opened, then they are closed on expiration.

Fig. 234 The specimen obtained by TBLB revealed well differentiated adenocarcinoma proliferating in papillary formation. As the specimen is not crushed the histologic features can be clearly recognized.
Fig. 235 A case of thyroid carcinoma metastatic to the lung appeared as a disseminated shadow on chest X-ray film. Here forceps (FB-19C) inserted to the periphery of B4a are opened for biopsy.

Fig. 236 The TBLB specimen revealed adenocarcinoma proliferating in a pattern resembling thyroid follicles and a diagnosis of metastatic thyroid carcinoma was made.
Fig. 237 Disseminated shadows varying in size from miliary to several millimeters in size were observed in both lung fields. Here the FB-19C is inserted into the periphery of B3a and the tip has been deflected in a hilar direction by the visceral pleura. Biopsy yielded a diagnosis of miliary tuberculosis.

Fig. 238 The biopsied lung tissue showed granuloma composed of epitheloid cells and fibroblasts and in the center of which a lesion of coagulation necrosis can be seen. This was diagnosed as a tuberculous granuloma. Sputum smears and culture revealed acidophilic bacilli.
Fig. 239  Sarcoidosis was suspected due to enlargement of the mediastinal and hilar lymph nodes. Although no abnormality was recognized in the peripheral lung field, TBLB was performed at three sites, $B^{1+2}$, $B^5$ and $B^{10}$. This figure shows forceps grasping lung tissue inserted through $B^4$.a.

Fig. 240  Histology of a site in the lung that showed no abnormality roentgenographically. Granuloma composed of epitheloid cells can be seen proliferating beneath bronchiolar mucosa. Occasionally foreign body type and Langhans giant cells can be seen but there is no necrotic lesion. A diagnosis of sarcoid nodule was made.
Fig. 241  Ill-defined infiltrative shadows were recognized at several locations in this case. Here the FB-19C forceps are inserted to the relatively better defined lesion in the periphery of B^4 a.

Fig. 242  Biopsied lung tissue. The alveolar wall is thickened and fibrous with organization in parts and collapse of the alveolar lumens can be seen. Fibrosing alveolitis was diagnosed.
Transbronchial Needle Aspiration Biopsy (TBAB) (Figs. 243–249)

Despite the remarkable progress in the diagnosis of respiratory tract diseases as a result of improvement in instruments and techniques, some cases which are exceptionally difficult to diagnose are occasionally encountered. Such lesions which are difficult to diagnose are those in the lung parenchyma in contact with the trachea, main bronchus or lobar bronchi beyond the bronchial wall in which pathological changes have not extended to the bronchial submucosa. Other cases difficult to diagnose are those beyond the bronchial wall of fourth and fifth order bronchi (subsubsegmental and subsubsubsegmental). In some of these diagnosis can be made by percutaneous needle biopsy, but in some cases this procedure is not indicated because of the proximity of large pulmonary blood vessels and the accompanying danger of massive bleeding should they be punctured. In such cases TBAB via the fiberoptic bronchoscope has been performed for more than seven years at the authors' institution. First the relationship between the bronchus and the lesion is carefully evaluated on the basis of tomography, computed tomography (CT) and, if possible pulmonary angiography findings, in order to determine the puncture site. The biopsy needle catheter (NM-3K) is inserted through the fiberscope with its retractable needle inside its sheath, up to the tip of the fiberscope. The fiberoptic bronchoscope is then inserted as in a conventional bronchoscopy procedure and after the target site has been reached, it is pressed lightly with the tip of the instrument. Then the tip of the needle is extended and both it and the fiberoptic bronchoscope are pressed firmly into the target site, penetrating the bronchial wall. Attempts at puncture merely by advancing the needle projected from the fiberscope will generally fail. A 20 ml disposable syringe is attached to the other end of the needle catheter and the fact that neither blood nor air is aspirated is checked. Then aspiration is performed moving the tip slightly backwards and forwards and to the right and left (10 sec. in each direction), after which the plunger of the syringe is freed, allowing it to return to a neutral pressure position, the tip of the needle is retracted and the entire needle catheter is withdrawn. The specimen in the needle is expelled onto a slide glass by air pressure from the disposable syringe, and it is immediately fixed in isopropyl alcohol and stained (Papanicolaou). The bronchofiberscope is withdrawn after it has been confirmed that there is no bleeding from the puncture site. If there is bleeding, the puncture site is pressed with the tip of the fiberoptic bronchoscope until the bleeding halts, which is generally within three minutes.

It is necessary to have a good understanding of pulmonary anatomy, especially the distribution of the pulmonary vasculature. Boyden reported on the distribution of the pulmonary vasculature in great detail. In general, since the pars interlobaris of the pulmonary artery is located close to the anterolateral wall of the bifurcation of the right upper lobe bronchus and the truncus intermedius, while the pulmonary vein (V^2) is located along the anterior wall, puncture of the medial wall in the upper lobe bronchus or the truncus intermedius is therefore generally safe. At the bifurcation of the left upper and lower lobe bronchi and that of the truncus intermedius and the middle lobe bronchus, the
middle of the bifurcation should be aimed at. In the left and right basal bronchi, since the pulmonary artery distributes along the lateral wall of the bronchi, the medial wall should be punctured for TBAB. However as there are individual variations in vascular distribution, including anomalous vessels, as has been mentioned previously, it is important to carefully examine the results of tomography, CT and if possible pulmonary angiography, prior to deciding the site of puncture for TBAB.

Naturally, TBAB can yield false-negative results. This can be the result of insufficient penetration of the needle, as shown in Fig. 243 b, c, or else of failure to enter the lesion. This can be overcome by making a small aperture in the bronchial wall by means of a transendoscopic electrosurgery cutter, followed by insertion of the TBAB needle or biopsy forceps, as shown in Fig. 243 d, e, f.

Fig. 243 Situation in transbronchial aspiration biopsy (TBAB).
Fig. 244 The bifurcation of the right upper lobe bronchus and the truncus intermedius was widened and the mucosal folds indistinct while the engorged submucosal vessels appeared to have proliferated. Here a modified NM-3K (needle slightly longer, narrower and a sharper bevel) is inserted through the bronchial wall at the bifurcation near the membranous portion and aspiration is being performed. There is no large pulmonary vessel at this location therefore the danger of vascular puncture and massive bleeding is minimal. In experiments in large animals puncture of large pulmonary vessels failed to cause uncontrollable bleeding.

Fig. 245 Clumped and finely granular chromatins can be seen. Nucleoli are frequently not recognizable in cytologic specimens obtained directly from adenocarcinoma lesions.
Fig. 246 A small aperture is being opened with the transendoscopic high frequency electric cutter in the membranous portion of the right wall of the carina. The right pulmonary artery distributes along the anterior wall of the right main bronchus and the site being punctured here holds little danger of puncturing a major vessel.

Fig. 247 Biopsy forceps are inserted through the aperture made by the high frequency cutter. After insertion through the wall, the forceps are opened, advanced and closed, then withdrawn through the fiberoptic bronchoscope. On the lateral side of the aperture into which the forceps are inserted, whiteness and slight edema can be seen.
Fig. 248 These are the findings immediately after the withdrawal of the biopsy forceps shown in the previous figure. The slight amount of bleeding halted after compression by the tip of the fiberoptic bronchoscope for 2–3 minutes. Usually the aperture heals completely in 1–2 weeks. There are no complications such as fever that would suggest mediastinitis. Only cases in which lymph node swelling is recognized are indications for histologic needle biopsy. However, even if lymph node enlargement is not clearly recognizable, TBAB can be performed safely and without danger, while the effectiveness of this method is enhanced by the method of opening a small aperture in the bronchial wall electrosurgically prior to the procedure.

Fig. 249 Histology of the carinal lymph node obtained by biopsy through the aperture in the bronchial wall, revealing moderately differentiated adenocarcinoma.
Therapeutic Procedures with the Fiberoptic Bronchoscope

Until 1975 the fiberoptic bronchoscope was primarily employed for diagnostic purposes, but recently its therapeutic applications have expanded and it is now an indispensable instrument for treatment of lesions located as far as segmental bronchi. As of 1983, the authors use the fiberoptic bronchoscope for the therapeutic procedures detailed in Fig. 250.

Fig. 250 Therapeutic applications of the fiberoptic bronchoscope.

1. Endoscopic laser treatment
2. Endoscopic electrosurgical treatment
3. Endoscopic mechanical treatment
4. Removal of foreign bodies
5. Intratumoral injections
6. Bronchial toilet
7. Tamponade hemostasis
8. Selective pressurized inflation
Endoscopic Treatment

Endoscopic treatment, particularly widening of the airway, has come to be aggressively performed in cases of nonresectable tumors, recurrence or cases in which poor cardiopulmonary function precludes invasive surgery.

Endoscopic treatment can be performed in the tracheobronchial tree as far as segmental bronchi. The purpose of most procedures is excision or vaporization of lesions occupying or obstructing the airway lumen and by so doing to reestablish the patency of the airway. There are primarily three methods at present to perform endoscopic surgery: 1) electrosurgery using high-frequency current, 2) debulking of tissue by high-energy laser, 3) mechanical excision by biopsy forceps. Ideally each case should be treated on an individual basis with the method or methods most suited to its conditions.

Lasers that can be employed via the bronchoscope include the CO₂ gas, Nd-YAG (neodymium-yttrium, aluminum, garnet), argon, argon dye, and krypton lasers. Each laser has its own characteristics, including wavelength and power (Table 7). All the above except the CO₂ laser, which has a wavelength too long to be transmitted by presently available quartz fibers, can be employed via the fiberoptic bronchoscope. In cases of central type early stage lung cancer, the argon dye laser can be employed to excite a tumoriphilic substance, hematoporphyrin derivative, with cytocidal effects. Since the power of this laser is extremely low, it has the advantage of tumor-specific effects, with little or no effects on surrounding normal tissue. On the other hand, in cases of stenosis or obstruction of large bronchi complaining of respiratory distress, the high-energy Nd-YAG laser can be used for rapid vaporization to open the airway. This can result in improvement of the patient's performance status, rendering possible the performance of other suitable methods of treatment such as radiotherapy or chemotherapy. Until the advent of the laser, extreme difficulty had been experienced in trying to open the airway in cases complaining of orthopnea due to tumors in the trachea or main bronchi. With recent developments in lasers it is now possible to debulk such tumors, leading to significant improvement in symptoms and the hope of extension of the period and quality of survival. Candidates for endoscopic treatment include the following:

1) Tuberculous or post-trauma cicatricial stenosis
2) Granulomatous changes following tracheoplasty or bronchoplasty
3) Benign and low-malignancy tumors of the trachea and bronchus
4) All primary, recurrent and metastatic tumors causing stenosis or obstruction of the trachea or bronchus in postoperative or inoperable cases
5) Inoperable central type early stage squamous cell carcinoma
Table 7  Comparison of lasers in endoscopic treatment in the trachea and bronchus

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<th>CO₂ Laser</th>
<th>Nd-YAG Laser</th>
<th>Argon Laser</th>
<th>Argon Dye Laser</th>
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<td>2. Can be employed with the fiberoptic bronchoscope under local anesthesia</td>
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<td>Disadvantages</td>
<td>1. Employed only via the rigid bronchoscope</td>
<td>1. Danger of damage to large blood vessels or airway wall</td>
<td>1. Danger of damage to large blood vessels or airway wall</td>
<td>1. Photoradiation requires much time</td>
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<td>2. Danger of damage to large blood vessels or airway wall</td>
<td>2. Ventilatory distress due to aspiration of smoke</td>
<td>2. Ventilatory distress due to aspiration of smoke</td>
<td>2. Ventilatory disturbances due to edema and severe necrosis can develop after procedure</td>
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<td>3. Ventilatory distress due to aspiration of smoke</td>
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The most common complication of endoscopic treatment is bleeding. Therefore it is essential that the operator continuously bear in mind the vascular anatomy surrounding the trachea and bronchus. The number of cases in which endoscopic surgical treatment is indicated is limited, but it can be performed in certain cases in place of the much more invasive conventional thoracotomy and in these cases holds great promise.

Furthermore, endoscopic surgery can generally be performed via the fiberoptic bronchoscope under local anesthesia, except of course in young children.

**High-frequency Electrosurgical Treatment** The first attempt to employ high-frequency current in endoscopic surgery was made approximately 60 years ago by Stern who performed prostatic resection via the cystoscope. Subsequently it became widely employed in the fields of cystoscopy, bronchoscopy and endoscopy of the digestive tract. Recently compact and safe high-frequency power sources have been developed and marketed (Fig. 251). The general layout of the method performed via the fiberoptic bronchoscope is shown in Fig. 252. The power source permits selection of cutting current, coagulating current, or a blend of the two. When the cutting probe is advanced close to the tissue sparks are emitted and the cutting is performed by the cells being boiled instantaneously. When using the cutting current, hemostatic effects are minimal. When the blended current is used the alternating coagulating current creates a thin coagulated layer which permits simultaneous cutting and coagulation. The authors usually use a flattened probe (see Fig. 5-[18]), lightly touching the tissue with it. If the probe is pressed strongly against the bronchial wall there is the danger of cutting a greater amount than intended and of perforation. The probe is moved slowly, trying to maintain it at the exact distance at which sparking occurs. After cutting, the tissue is removed by conventional biopsy forceps or by electric current passed through so-called hot biopsy forceps.

This procedure can be useful for cutting in sites that are difficult to treat by the Nd-YAG laser method described later in this section, or to remove necrotic materials after laser treatment. When opening a small aperture in the bronchial wall for TBAB or for biopsy of extrabronchial lymph nodes, the blended current is used. While the cutting, debulking and hemostatic effects of the electrosurgery system are not as good as those of the Nd-YAG laser, the former is one thirtieth the price of the latter, and it is easier to use, particularly for fine maneuvers in subsegmental bronchi (Figs. 253—256).
Fig. 251  A high-frequency power source (Olympus UES), footswitch, probe and patient plate.

Fig. 252  The general layout of high-frequency electrosurgical treatment by a fiberoptic bronchoscope.
A 65 year-old male presented with respiratory distress, difficulty in expectoration of sputum and stridor. His chest X-ray film revealed no abnormal findings. Here a large multinodular tumor with its base in the membranous portion extends from the mid- to inferior portion of the trachea. The tumor is relatively localized and there is no invasion to the superior portion of the trachea. Vessels are clearly seen in the mucosa which completely covers the tumor. The tumor extends to the proximity of the carina, where it protrudes in an anterior direction, preventing the insertion of the fiberoptic bronchoscope into either main bronchi. Biopsy yielded a diagnosis of adenoid cystic carcinoma.

The findings one week after the first electrosurgical treatment procedure. Necrosis and accumulation of secretions can be seen on the cauterized surface. His symptoms had disappeared at this stage.
Fig. 255 These are the findings one week after the fourth electrosurgical treatment. The tumor has been almost completely removed. Protrusions on both sides of the membranous portion were shown by biopsy to contain a mixture of granulomatous tissue and tumor. Since this tumor was malignant, when the patient's condition permitted, surgery was performed and replacement of the membranous portion with a patch (artificial aortic graft) was carried out. Tracheal resection and end-to-end anastomosis was not performed because the extent of resection required would have been 7 cm (14 cartilage arches).

Fig. 256 Ten weeks after surgery, the patch protruded into the tracheal lumen, causing stenosis, therefore tracheotomy was performed, the patch was removed and the granular tissue was vaporized by Nd-YAG laser. These are the findings one year later. No recurrence can be seen. High-frequency electrosurgical treatment in this case was effective in improving his general condition and simplifying surgery and anesthesia.
Nd-YAG Laser Methodology In respiratory and digestive tracts, lasers were at first only employed during invasive open surgery. The first report concerning the delivery of laser light by means of an optical fiber inserted through an endoscope was in 1973. The first report of a laser beam employed in combination with bronchoscopy was that of Strong et al. in 1974 who successfully vaporized papilloma of the airway and treated bronchial stenosis by means of a CO₂ laser via a rigid bronchoscope under general anesthesia. The first clinical application of a laser beam with a fiberoptic endoscope was made by Frühmorgen et al., who in 1976 reported the transendoscopic hemostatic treatment of gastric bleeding by means of an argon laser. Because of its extremely long wavelength, the CO₂ laser cannot be transmitted by quartz fibers available today and therefore at present it is not practical for use with flexible fiberoptic endoscopes.

Lasers that are being used today in combination with the fiberoptic bronchoscope include the Nd-YAG laser, argon laser, argon dye laser and krypton laser. Since the wavelength of the Nd-YAG laser is in the infrared range (1,064 nm), it is not visible to the human eye, therefore a coaxial low-energy helium-neon (He-Ne) beam is incorporated in the laser system as a pilot beam to show the exact spot at which the fiber is pointing. A high energy output is used for tissue destruction and vaporization, whereas a relatively lower energy output is employed for hemostasis. The argon laser beam is tunable from 488 to 514.5 nm and its color is a brilliant green. It has been reported as suitable for coagulation of blood and tissue. Compared to the Nd-YAG laser the danger of its perforating the airway wall is lower, but it is not suitable for tissue destruction and vaporization and can be dangerous to the retinas of the operator, assistants and patient. In the argon dye laser system, an argon laser is used to pump a dye laser that converts the beam to a different wavelength (630 nm) in order to obtain maximum tissue penetration for photoactivation of a tumorphilic substance, hematoporphyrin derivative (Hpd), which has previously been administered to the patient. Since Hpd is discharged by normal tissue, remaining in malignant tissue, this method has the advantage of making it possible to selectively treat only areas of malignancy. The energy of the argon dye laser beam is generally very low (100–300 mW) therefore its effectiveness appears to be primarily due to its photodynamic effect on the Hpd rather than to thermodynamic effects. Incidentally, it may be noted that this method does not require a laser light source as an absolute necessity, rather lasers have come to be used because they are capable of providing coherent light with a wavelength of the greatest tissue penetration potential and also, more importantly, because they are very convenient for delivery of light through quartz fibers inserted via the instrumentation channel of fiberoptic endoscopes. Due to the low energy level of the beam, this method is different from other high energy laser treatment methods in that it has little or no effect on surrounding normal tissue, being specifically effective on malignant tissue. However, the structure of the normal bronchial wall serves to attenuate to some degree the penetration by the argon dye laser beam, therefore if an area of invasion is covered by a normal area of the
APPLICATIONS OF FIBEROPTIC BRONCHOSCOPY

bronchial wall it is difficult to obtain satisfactory penetration and effectiveness. The effectiveness of this method is necessarily limited by the extent of light penetration, but it can be effective in superficial lesions limited to the bronchial mucosa.

On the other hand the Nd-YAG\(^6,24\) can be effective not only in malignant airway tumors but also benign tumors and benign stenosis. However, by the same token, it must be remembered that this method is not selective for malignant tumors and the beam will vaporize whatever tissue it comes in contact with. The authors and their colleagues began basic research on applications of the Nd-YAG laser via the fiberoptic bronchoscope in 1978\(^5,35\), and began employing it clinically in 1980\(^8,5\). The laser we use and the methodology are shown in Figs. 257 and 258.

![Fig. 257 Olympus Nd-YAG laser.](image1)

![Fig. 258 Nd-YAG laser treatment.](image2)

**Work-up and Procedure**

As described in the chapter on the insertion of the fiberoptic bronchoscope, after administration of atropin sulfate and local anesthesia the patient is requested to lie on the examination table in a supine position and the fiberoptic bronchoscope is inserted directly transorally, without using a tracheal tube. The quartz fiber to transmit the laser beam is inserted through the instrumentation channel and projected about 5 mm from the tip of the fiberoptic bronchoscope, keeping it 5—10 mm from the target. In cases with a PaO\(_2\) of 60 torr or less under
oxygen administration, cases with a strong cough reflex, and particularly nervous cases 15—30 mg pentazocine and 10 mg diazepam are administered i.v. in order to facilitate the procedure. Apart from cases preprocedurally complaining of severe dyspnea, in principle oxygen is not administered during the procedure for safety reasons and the procedure is performed safely while the patient breathes spontaneously. In cases in which oxygen administration is necessary, it is given via an intranasal catheter. The smoke caused by the vaporization of tissue can induce cough. Therefore suction is performed continuously through the instrumentation in which the quartz fiber is inserted and through a suction evacuation tube placed in the oral lumen. Furthermore, since there is a need to protect the tip of the fiber and the lens of the fiberoptic bronchoscope from attachment of fragments of carbonized material during the vaporization process, air is pumped through the teflon sleeve of the quartz fiber.

**Points Requiring Caution**

1) The high energy beam of the Nd-YAG laser causes instantaneous elevation of the temperature of tissue, causing evaporation of intracellular water, combusting organic compounds, as a result of which the tissue is vaporized and disappears. Compared to the CO₂ laser, the energy of the Nd-YAG laser is transmitted relatively more to surrounding tissue⁵,⁶). The relatively widespread thermo-coagulation effect in tissue causes good hemostatic effects and also makes for good thermodynamic effect on tissue. However, these properties also mean that it is less effective as a dissecting cutter.

2) The effects of the Nd-YAG laser beam are known to vary with the color of the object. Beams of the same power will have greater effect on darker objects than on white objects.

3) The effects of the Nd-YAG laser beam are influenced by the amount of interstitial tissue, with more energy being required for tissue containing much interstitial tissue.

4) Normally, for vaporization of tumors causing obstruction or stenosis, a power output of 70—80 W is used in one-second shots. However for lesions limited to within the bronchial wall, a power output of 50 W in 0.5-second shots can obtain vaporization of invasion. Care is exercised to keep the spot accurately on the target surface⁷,⁴). For lesions in the bronchial wall, treatment or biopsy to determine the necessity of further laser treatment is performed at one-week intervals.

5) In order to ensure safety when performing Nd-YAG laser treatment endoscopically, it is necessary to be flexible in approach as each case can vary significantly in terms of the patient’s condition as well as the nature and location of the lesion. In cases of space-occupying lesions in the trachea or continuous from the trachea to main bronchi accompanied by severe ventilatory disturbance the procedure should be performed to open and maintain the airway, thereby enabling improvement of the general condition of the patient. Almost all Nd-YAG laser procedures performed via the fiberoptic bronchoscope are emergency life-saving procedures.
6) In procedures performed to improve ventilatory disturbance it is not necessary to completely eradicate the entire lesion on the occasion of the first session. It is enough if a 6 mm fiberoptic bronchoscope can be inserted without the patient complaining of ventilatory disturbance. Usually exfoliation after necrotic change is recognized over several days, but if necessary, further treatment can be performed 7—10 days later.

7) Cases of a tracheal tumor almost obstructing a main bronchus in which the location of the carina is not clear are sometimes encountered. Such cases are indications for treatment by Nd-YAG laser on the condition that there is no large tumor shadow on the involved side, but extreme caution must be exercised in searching for the carina and performing treatment. First the lesion in the trachea is cautiously and gradually vaporized. Usually in cases in which the main bronchus may be opened, slight movement in one part can be seen on respiration and in the center of this portion a small aperture is opened. When connection is made with the main bronchus the secretions that have accumulated on the distal side spur through as from a sluice. After the secretions have been aspirated the small aperture is gradually widened. If no such movement on respiration can be recognized, attempts to open an aperture blindly are accompanied by the danger of perforation and massive hemorrhage, therefore the procedure is halted on that day. After 7—10 days later a second treatment session is attempted and it is sometimes seen that the thermal effects of the laser have caused shrinkage of the tumor, revealing a slight gap between the tumor and bronchial wall or movement on respiration. However, if the orifice of the main bronchus is still not recognizable on the second procedure then it must be considered impossible to treat the case by this modality.

8) Unlike in the case of malignant tumors, Nd-YAG laser treatment can be used instead of thoracotomy for the curative treatment of benign tumors protruding from the tracheal or bronchial wall. In many cases the base of the tumor is relatively small. For the head of the polyp a power output of 70—80 W in shots of 1—2-seconds is used, tub for the base of the tumor 0.5-second shots of 50 W power are used. In treating the tumor, it is necessary to be careful to minimize the effects on normal tissue.

9) Nd-YAG laser treatment can be indicated in cases of lesions located from the trachea to the segmental bronchi.

10) In cases of inadvertent vaporization of normal tissue, reepithelization is recognized within two weeks. The area where the tumor was vaporized also becomes covered with mucosal epithelium about two weeks after the procedure. Areas of remaining tumor tissue are seen to be covered with necrotic material after three weeks or more, therefore it is necessary to perform the laser treatment procedure again in areas in which necrotic materials are recognized two weeks after the first procedure as these areas are thought to be the site of remaining tumor.

11) Within 24 hours after the vaporization procedure, fever and a condition resembling asthma can occur, probably due to inhalation of smoke. This is particularly frequent in cases which preprocedurally complained of bronchitis or
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bronchopneumonia. The authors perform repeated bronchial toilet procedures with the fiberoptic bronchoscope after the procedure to remove the voluminous secretions that appear after the procedure and also administer antibiotics, prednisolone and, if necessary, oxygen.

12) In cases of decreased ventilatory volume, particularly cases of reduced ipsilateral pulmonary function, acute respiratory insufficiency can develop after the procedure, also probably due to smoke inhalation, therefore thorough postprocedural care is essential.

Indications

Endoscopic Nd-YAG laser treatment is only indicated in those cases in which the respiratory tract distal to the obstruction or stenosis is physiologically viable from the point of view of ventilation and circulation. Furthermore in cases in which two or more cartilage arches have been destroyed by tumor, even if the airway is widened by this procedure it will collapse, therefore such cases are considered contraindications.

The role of transendoscopic Nd-YAG laser treatment in lung cancer cases is as a local adjuvant modality in cases undergoing combined therapy, such as surgery, radiotherapy and chemotherapy. It is only indicated and successful in a small number of cases. The only type of case in which this treatment might have any potential as a single therapeutic modality is central type early stage lung cancer. However, even in early stage cases, it can be difficult to perform adequate laser radiation of lesions in areas around segmental bronchial bifurcations, where a direct frontal approach is not possible.

Cases of lung cancer in which endoscopic Nd-YAG laser is indicated are naturally primarily limited to lesions in large airways with no peripheral lesions and also cases in which there is little tendency toward submucosal invasion or intramural lymphatic invasion. From this point of view, cases of squamous cell carcinoma in the trachea or trachea and bronchus, adenoid cystic carcinoma, mucoepidermoid carcinoma or carcinoid originating in the main bronchi can be indications. It is also indicated as a palliative treatment to widen the airway and improve the general condition in cases of lung cancer located from the trachea to lobar bronchi in which the peripheral respiratory tract is functional. This modality has been performed primarily as an emergency procedure, even in cases of lung cancer, and is only one arm of the multidisciplinary therapeutic approach to lung cancer. It can be indicated in cases of lesions which are mostly within the airway lumen and in which there is no peripheral lesion. However, clinical experience with lung cancer rapidly teaches one that there is generally only at most one real chance to combat the disease after it is detected, and that if success is not met with on that occasion, then the outlook is indeed bleak. From this point of view, endoscopic Nd-YAG laser treatment can hardly be expected to obtain encouraging results in cases in which the effects of other therapeutic modalities, such as radiotherapy or BAI have already been overcome by the natural history of the disease.
Indications of Nd-YAG laser treatment in benign diseases include benign tumors or cicatricial stenosis located from the trachea to the segmental bronchi. The most favorable indication is benign tracheal tumor and the method is now considered valuable as replacing thoracotomy as a single radically therapeutic procedure. In the case of cicatricial stenosis, only scars with a base in the bronchial wall of less than 1 cm in length are indications for the procedure. Also, the procedure is not indicated in cases which do not show complete cicatrisation and have some remaining inflammatory aspects, especially active tuberculous granuloma or cases positive for tuberculosis bacilli, because following treatment they will exhibit remarkable reactive granular proliferation.

Most metastatic cases in which this procedure is indicated are tumors metastatic to the trachea. In such cases complaining of ventilatory disturbance, endoscopic Nd-YAG laser treatment can be indicated as an emergency procedure. However, in most cases this only results in a short prolongation of survival. In a small number of cases extension of survival for over a year is obtained, but these are cases in which the primary tumor has been effectively treated and in which this procedure is performed to improve the patient's condition so that chemotherapy or radiotherapy can be performed.

Finally, endoscopic Nd-YAG laser treatment can be indicated in cases of bleeding. Hemostatic effects can be obtained throughout a fairly wide area, using a power output of 40–50 W. From this point of view, hemostasis can be performed from the trachea to the segmental bronchi, regardless of whether the case be malignant or benign. However, cases of widespread bleeding, as in necrotizing bronchitis are not indications. It is indicated only in case of bleeding from specific and recognizable points.
Fig. 259  A squamous cell carcinoma covered with necrosis was recognized in the left lower lobe bronchus of a 76 year-old male. Surgery was contraindicated because of the poor pulmonary function. Nd-YAG laser treatment was performed because of continuing fever of 38°C due to obstructive pneumonia in the left lower lobe. Chest X-ray film showed the lesion to be located in S6 and the tumor seen endoscopically was therefore considered to project from B^6. It was therefore considered that vaporization of the tumor would allow ventilation of the basal segment.

Fig. 260  The same case as in the previous figure. The tumor had developed from B^6 as a polypoid lesion and was relatively localized. These are the findings on beginning treatment with 2-second shots of 40W power.
Fig. 261 Immediately after the laser procedure the tumor is seen to have been vaporized and carbonization of remaining tumor and bronchial mucosa can be seen. Ventilation of the basal segment of the lung became possible and the obstructive pneumonia disappeared.

Fig. 262 One week after treatment in the case shown in the above three figures. The submucosal bleeding seen at the orifice of the lower lobe bronchus is a result of the laser treatment.
Fig. 263 A 75 year-old male case of squamous cell carcinoma complained of severe ventilatory disturbance (\( \text{PaO}_2 \) on admission: 58 torr). Even receiving oxygen he had to remain sitting to breathe. Chest X-ray film revealed no tumor, atelectasis or obstructive pneumonia in either lung field. However the entire left lung showed pulmonary emphysema and the left diaphragm appeared depressed. Tomograms indicated that the tumor developed in three directions from the carina, to the trachea and to each main bronchus. Laser radiation was performed to improve the patient's condition and render him a candidate for radiotherapy and chemotherapy.

Fig. 264 The same case as in the previous figure, seven days after treatment with 21,336 Joules at a power level of 60–80 W. The first treatment allowed maintenance of the right main bronchus, however because of the extremely marked invasion of the left wall of the carina the orifice of the left bronchus could not be determined on this occasion. The white areas in this figure are areas of exposed cancer.
Fig. 265 The same case as shown in Fig. 263, one week after the first treatment. On the second occasion a part of the necrosis-covered tumor was observed to move on respiration and after a small aperture was made at that site, a flood of pent-up secretions appeared. After aspiration of the secretions the left main bronchus was opened by 3,009 Joules at a power level of 55 W. Following treatment his Pao2 was 78 torr breathing room air and he later received radiotherapy and chemotherapy.

Fig. 266 In the same case as shown in Fig. 263, ten months after completion of a course of 60 Gy Linac radiotherapy. The site of laser vaporization shows good regeneration of the mucosa, the widened bifurcation has become sharper and remarkable improvement in local and general condition was recognized. These findings were seen one week after biopsy of an area at the bifurcation covered by necrosis. The biopsy contained no malignant cells. Laser treatment was considered effective in this case for several reasons; it was squamous cell carcinoma, most of the lesion was in the airway lumen, it was not a case of relapse but rather the endoscopic laser treatment was the first step in a multimodality therapeutic approach.
Fig. 267 A 45 year-old male had suffered recurrent episodes of right middle lobe obstructive pneumonia and had received treatment for the common cold by his local physician over a period of a year. A three-day pooled sputum specimen six months earlier had been negative for malignancy. He was referred for recurrence of pneumonia. The widening of the carina suggested metastasis to the subcarina lymph nodes. The tumor appears to have developed from the right main bronchus to beyond the bronchial wall and was thought to extend to the left main bronchus. Endoscopic Nd-YAG laser treatment was considered to be indicated in order to obtain relief from fever accompanied by obstructive pneumonia, since there was no peripheral lesion and since this was his first treatment of the malignancy.

Fig. 268 In the same case as shown in the previous three figures, ten months after the patient was referred for treatment, the widening of the carina displayed remarkable improvement. Endoscopically the results of Nd-YAG laser treatment and other combined therapeutic modalities appeared to have resulted in disappearance of the carcinoma and the entire bronchial wall was covered by regenerated normal bronchial mucosa. In this case of adenocarcinoma endoscopic Nd-YAG laser was thought to have been effective as one part of a multimode therapeutic strategy.
Fig. 269  This 70 year-old male, suffered from dyspnea on exercise. A polypoid tumor with a glossy surface obstructs the left main bronchus. No invasion can be recognized in surrounding bronchi. Biopsy yielded a diagnosis of carcinoid. As this case was evaluated to be inoperable due to poor lung function and hepatorenal insufficiency and taking into consideration the fact that this was a low grade malignant tumor, endoscopic Nd-YAG laser treatment was performed.

Fig. 270  In the case shown in Fig. 269, five months after the first treatment. Endoscopic Nd-YAG laser treatment was divided into weekly sessions with a total of 22,127 Joules. No other therapy was performed. The tumor disappeared and the site where the base of the tumor had been located shows good regeneration of the mucosa. This was considered a complete cure.
Fig. 271 A multinodular tumor can be seen protruding from the right wall of the trachea. Air passed through the small opening between the tumor and the left wall of the trachea. In this case of orthopnea even with a 5l/min O₂ nasal cannula and a 15l/min O₂ tent the PaO₂ was 58 torr. The tumor had proliferated covered by the normal mucosa. Distended vessels can be seen in the mucosa covering the tumor. Biopsy yielded a diagnosis of adenoid cystic carcinoma.

Fig. 272 After 553 1-second shots of 40 W the lesion was partially vaporized and the left half of the trachea was opened. The carina and the left main bronchus became visible. The patient's respiratory distress was eliminated and immediately after the procedure he could walk by himself. At this point his PaO₂ in room air was 76.4 torr and the PaCO₂ was 31 torr.
Fig. 273 The second day after the first laser treatment of the same case shown in the previous two figures, tumor tissue thermally affected by the laser beam was removed by means of the electrosurgical high frequency cutter and biopsy forceps, thereby widening the tracheal lumen even more. In the surrounding area carbonizing effects of the laser beam are seen, in addition to extensive submucosal bleeding. An exfoliated portion of the tumor, 8 mm in size, can be seen in the right lower lobe bronchus.

Fig. 274 In the same case 21 days after the laser treatment, removal of tissue also performed by electrosurgery and biopsy forceps on the 2nd and 14th day after the laser procedure, a tumor covered by necrosis was recognized in the right tracheal wall, but the lumen of the trachea had been opened to an almost normal width and distal to it, the left and right main bronchi could be observed. As can be recognized from the course of this case, the laser treatment was performed only once, but after the treatment secondary effects resulting in contraction of the tumor were recognized with expansion of the airway lumen. As tumor remained in this case, when his condition had improved to allow him to tolerate surgery, tracheal resection and end-to-end anastomosis was performed.
Fig. 275 This is a case of tracheal invasion following surgery for esophageal carcinoma. Only a slight aperture remains between the tumor protruding in the mid-portion of the trachea and the tracheal wall. Submucosal invasion extends all around the tracheal wall and the right lateral wall of the trachea proximal to the tumor is distended due to extramural compression of the tumor. On the surface of the tumor proliferation and engorgement of neoplastic vessels and adhesion of secretions can be recognized.

Fig. 276 This figure shows the findings immediately after the tumor shown above was vaporized by the Nd-YAG laser (2,815 Joules). The chest wall of the patient started to move significantly and his symptoms improved remarkably. Before the procedure his $\text{PaO}_2$ of 48 torr and $\text{PaCO}_2$ of 51 torr, breathing room air, improved to 66 torr and 48 torr immediately after the procedure, and the next morning they were 90.2 and 42.9 torr, respectively.
Fig. 277 This 60 year-old female had undergone left pneumonectomy 23 years previously because of tuberculosis. Several years previously she developed exertional dyspnea. Here the trachea shows remarkable stenosis and it is impossible to observe the carina. The cartilage near the stenotic site is deformed and covered with glossy cicatricial formation. The tracheal lumen is stenotic due to tuberculous cicatricial formation.

Fig. 278 These are the findings two weeks after the laser treatment and electrosurgical treatment were performed twice each. Redness is recognized all around the trachea, but the stenotic portion is dilated, her symptoms had disappeared, the treated region is covered by mucosa and she could expectorate sputum easily.
A 35 year-old male presented with repeated episodes of cough and fever over a period of six months. Chest X-ray film showed atelectasis of S^3^ and fiberoptic bronchoscopy revealed a polyp in the right upper lobe bronchus that moved slightly on respiration. On expiration a slight opening was recognized between the polyp and the superior wall of the right upper lobe (on the right in this figure). Surrounding bronchi showed no abnormal findings and hamartoma originating in the bronchial wall was diagnosed by biopsy of the polyp.

The findings just after beginning treatment with 2-second shots of 80 W power in the case shown in the previous figure. Because of the white color of the tumor a little time was required before vaporization effects were recognized but thereafter the procedure proceeded smoothly. The polyp was homogeneous and was poorly vascularized.
Fig. 281 These are the findings in the same case shown in Fig. 279, immediately after completion of vaporization of the tumor. It was recognized that the tumor had originated from the anterior wall of B3 as it branched from the upper lobe bronchus. The base of the tumor was treated with 0.5-second shots of 50 W power, taking care to minimize effects in the normal bronchial mucosa. This case required no further treatment after the single Nd-YAG laser treatment session (1,575 Joules).

Fig. 282 One month after the single laser treatment session in the case shown in Fig. 279. Regeneration of the bronchial mucosa at the site of treatment and submucosal bleeding caused by coughing was observed. No abnormal findings were observed in the segmental bronchi. The chest X-ray film taken at this time revealed that the atelectatic shadow in S3 had disappeared.
Fig. 283 A 42 year-old male had received treatment for bronchial asthma for a period of ten years. Recognition of a tumor shadow immediately superior to the carina on chest X-ray film led to a fiberoptic bronchoscopy examination. A polyp that had developed from the left anterolateral wall was observed to move slightly on respiration. Insertion of the fiberoptic bronchoscope beyond the tumor revealed that the carina was normal. Biopsy revealed the tumor to be an extremely rare case of tracheal benign mixed tumor (pleomorphic adenoma).

Fig. 284 The findings after commencing treatment of the case shown in Fig. 283 with 2-second shots of 80 W power. The tumor was solid, homogeneous, poorly vascularized and as a result was easy to vaporize.
Fig. 285  After the single laser treatment of the case shown in Fig. 283 (11,300 Joules). In the anterior wall carbonized fragments that spattered from the lesion can be recognized and an area of the carina that was inadvertently carbonized.

Fig. 286  The same case as in Fig. 283, six months after laser treatment. Although one to two months after laser treatment granulomatous tissue had been seen at the site of deepest laser vaporization of the tumor base, at six months no pathological findings were observed. Histologically no tumor findings were obtained.
Intratumoral Injection (Fig. 287)

The first report concerning non-specific BCG immunotherapy was made in 1970 by Morton et al.\textsuperscript{66} who described not only local effects but also improvement in systemic immunocompetence as a result of intratumoral injection of BCG in cases of melanoma. The authors performed intratumoral injections of BCG and cell wall skeleton (CWS) preparations of BCG and Nocardia rubra\textsuperscript{*} by means of a modified NM-3K needle inserted through the fiberoptic bronchoscope in cases of lung cancer. Most cases receiving such treatment were inoperable stage III cases and the number of injections per case ranged from one to 32. The 12 month survival of cases in this group receiving BCG-CWS injections was 39.3\% as opposed to 18.2\% in controls not receiving this treatment. While this simple method was recognized to yield good local and systemic effects, no conclusion can be drawn until the completion of several on-going clinical trials.

Fig. 287 Intraleral injection. Right B\textsuperscript{1} and B\textsuperscript{2} are almost obstructed by tumor invasion. The longitudinal folds which continue from the main bronchus are thickened and tend in the direction of B\textsuperscript{2}. The thickening is the result of submucosal tumor invasion. The superior wall of the upper lobe bronchus (right foreground) is remarkably thickened and edematous. The anterior wall (upper foreground) still preserves relatively intact portions. This figure shows the direct intraleral injection of the cell wall skeleton of Nocardia rubra\textsuperscript{*} into the reddened tumor centered on the bifurcation of B\textsuperscript{1} and B\textsuperscript{2}. After the second fortnightly injection the tumor regressed remarkably. Squamous cell carcinoma – diagnosed histologically by biopsy.

\textsuperscript{*}Kindly provided by Professor Yuichi Yamamura, Department of Internal Medicine, Osaka University Medical School, Osaka.
Applications of Fiberoptic Bronchoscopy

Bronchial Toilet (Figs. 288–291)

Use of the fiberoptic bronchoscope as a bronchial toilet has also become more and more widespread. Almost all of the Japanese institutions responding to our survey78) indicated experience with this method. Use of the instrument as a bronchial toilet is not only of great therapeutic value in case of diseases of the lung, but also in the postoperative management of thoracic surgery cases, including cardiovascular and esophageal surgery cases. It is a routine postoperative procedure in all cases with diminished ability to expectorate sputum and is also absolutely essential in the management of airway burn cases77,78), postoperative neurosurgery cases and intensive care unit cases.

In the past bronchial toilet was carried out by means of blind suction through various catheters inserted via tracheotomy or an endotracheal tube. This type of approach results in an excessive reduction of humidity in the airway, thereby

Fig. 288 A 45 year-old male underwent surgery for an inguinal hernia under lumbar anesthesia and was kept at rest for 48 hours. On the first postoperative day he developed a fever of 38°C, stridor and slight respiratory distress, followed by gradual worsening of his condition. He had difficulty coughing because of his wound pain. Chest X-ray on the third postoperative day revealed atelectasis in the right lung and bronchial toilet was therefore performed. Viscous frothy sputum was found obstructing the right bronchus, from the inferior trachea to the subsubsegmental (fourth order) bronchi. Since aspiration of sputum with the BF-B3R was difficult the BF-1TR was employed.
reducing the biological ability of the cilia of the mucus membrane to move mucus and foreign material. Also, as the endotracheal tube has to be kept there for a long time, mechanically it is hazardous to the trachea, and damage to the mucus membrane can result in an increase in secretions. The method employing the fiberoptic bronchoscope is the only one which permits removal of airway secretions while giving minimal stimulus to the mucus membrane of the airways, thereby minimizing also possible damage to the functionality of the ciliated epithelium.

In the past, the prognosis of airway burn cases was exceptionally poor, with complications due to obstruction of the airways as a result of sloughing of the mucus membrane scab 4—7 days following the burn, bleeding of the scab or heavily viscous airway secretions, but removal of these under visual supervision by means of the fiberoptic bronchoscope can minimize such complications and save lives. It has been recognized as an absolutely indispensable tool in the management of such cases.

Fig. 289 The chest X-ray on the day following the bronchial toilet procedure in the case shown in the previous figure shows that while the air content of the right lung is reduced, there is some ventilation. His fever dropped to 37°C and his stridor diminished. Another bronchial toilet with the BF-1TR was performed.
Fig. 290  On the day following the second bronchial toilet procedure the chest X-ray findings showed further slight improvement, the stridor disappeared completely, as did his fever. The second bronchial toilet plus continued administration of antibiotics resulted in dramatic improvement of the patient's discomfort.

Fig. 291  The chest X-ray findings on the third day after the X-ray shown in the previous figure was taken shows almost normal findings. Bronchial toilet was extremely effective in the treatment of this case. Performing the procedure via the fiberoptic bronchoscope, unlike the case of blind suction via a catheter, allows minimal physical stimulation of the airway mucosa and observation to ensure removal of secretions in segmental and sub-segmental bronchi during the procedure. This is a technique that is indispensable in any unit treating pulmonary diseases.
Treatment of Airway Bleeding

The question of how to manage cases of bleeding in the airway tract has already been discussed in the introduction. Here the techniques employed in the control of bleeding in the authors' institution are described. Steps that must be taken to cope with bleeding are 1) aspiration of blood to maintain the airway, 2) determination of the bleeding side, 3) determination of the bleeding site, 4) determination of the amount of bleeding. Regardless of the underlying disease, it must be dealt with instantaneously and correctly. If bleeding is observed during a fiberoptic bronchoscopy procedure, the fiberoptic bronchoscope should not be removed. The patient should be rotated onto the side that is bleeding, in order to prevent blood being aspirated by the contralateral lung. Then the bleeding site should be compressed by the tip of the fiberoptic bronchoscope, or else the fiberoptic bronchoscope should be wedged in the bleeding bronchus. Bleeding halts in 3—10 minutes in cases with no coagulopathy.

Cases of hemoptysis should be treated as described previously (p. 159), i.e. the fiberoptic bronchoscope should be inserted transorally, and while performing aspiration the tip should then be advanced through the oral lumen, larynx and trachea. Once it has been determined which side the bleeding has occurred, the patient is rotated on that side for the reasons given above, the tip of the fiberoptic bronchoscope is inserted into the main bronchus of the bleeding side while performing aspiration and care is taken to ensure that no blood is aspirated by the contralateral lung (Fig. 292). Occasionally airway stenosis caused by blood clots as long as 10 cm are seen and these are removed by biopsy forceps while withdrawing the fiberscope at the same time. As the amount of bleeding decreases, the fiberoptic bronchoscope is advanced slowly, removing blood by aspiration and also biopsy forceps, searching for the site and cause of bleeding. In cases of bleeding originating from segmental bronchi or beyond, the tip is wedged into the

Fig. 292 Aspiration of blood with the fiberoptic bronchoscope.

Fig. 293 Hemostasis by wedging the fiberoptic bronchoscope in the segmental bronchus.

Fig. 294 Insertion of the cuffed tracheal tube into the contralateral lung via guidance by the fiberoptic bronchoscope.
segmental bronchus to cause coagulation within one segment (Fig. 293). When difficulty is experienced aspirating sufficiently with the routine instrument (BF-B3R, channel diameter 2 mm) the fiberoptic bronchoscope for treatment is employed (BF-1TR, channel diameter 2.6 mm).

Even in cases of bleeding of more than 200 ml/hr the fiberoptic bronchoscope can perform a life-saving role in maintaining the airway. While, as has already been stated, in most cases without coagulopathy the bleeding halts within ten minutes, some cases may require 60 minutes. In cases in which it is difficult or impossible to sufficiently aspirate, even with fiberoptic bronchoscopes for treatment, the healthy lung should be intubated with a tracheal tube with a cuff, then the cuff is inflated to prevent blood entering the healthy lung (Fig. 294). After 1—2 days the coagula formed in the bleeding side are removed by biopsy forceps via the fiberoptic bronchoscope. In such cases the tracheal tube used must have a cuff, otherwise blood will seep around the tube into the healthy lung.

**Selective Pressurized Insufflation (Figs. 295—299)**

In cases in which reexpansion of a collapsed lung is difficult, one possible option is pressurized insufflation of air via the fiberoptic bronchoscope in order to achieve reexpansion.

This procedure is performed after insertion of the fiberoptic bronchoscope as in routine procedures, i.e. local anesthesia and spontaneous respiration. After insertion the aspiration adapter is replaced by an AMBU bag and air insufflation of each segmental bronchus is performed with a pressure of 20—30 cm H₂O.⁵⁰

While most cases treated by this method do not generally show recollapse, in some cases poor expansion is obtained, therefore chest X-ray films should be referred to carefully when performing this method again.

After pressurized reexpansion localized pulmonary edema is sometimes recognized, but this is usually resolved within seven days. No apparent damage to alveoli has been recognized with pressures of up to 40 cm H₂O with this technique.
SELECTIVE PRESSURIZED INSUFFLATION

Fig. 295 A 23 year-old male case of cancer of the tongue underwent total tongue resection with half of the mandible and dissection of bilateral lymph nodes with oral lumen reconstruction by graft of the fourth rib to the mandible. On the third postoperative day right pneumothorax and collapse of the right upper lobe, probably a result of the rib resection, was recognized on chest X-ray.

Fig. 296 Immediately after the findings shown in the previous figure were recognized, a trocar catheter was inserted into the right thoracic cavity and continuous suction with $-10\text{cm H}_2\text{O}$ was performed. However only slight overexpansion of the middle and lower lobes was recognized, with no reexpansion of the right upper lobe. From the fifth postoperative day negative suction pressure was increased to $-20\text{cm H}_2\text{O}$, but no improvement was observed. On the first fiberoptic bronchoscopy procedure on the seventh postoperative day, only stenosis of all segmental bronchi in the right upper lobe was recognized, with no accumulation of secretions.
Fig. 297 The patient had undergone tracheotomy as part of the surgical procedure. Attaching a respirator to a tracheal cannula 40 cmH₂O pressure was applied but this only resulted in increased emphasis of the overexpansion of the middle and lower lobes. The right upper lobe remained atelectatic.

Fig. 298 Selective pressurized insufflation of the segmental bronchi via the fiberoptic bronchoscope was then performed. This figure shows the chest X-ray findings immediately after the first procedure. Although acute reexpansion pulmonary edema can be seen, the right upper lung is no longer collapsed.
Fig. 299 In order to prevent recollapse of the right upper lobe selective pressurized insufflation was performed twice a day for five days in each segmental bronchus of the upper lobe. The localized pulmonary edema disappeared. This figure shows the findings on the 17th postoperative day.
Experimental Carcinogenesis in Large Animals

The combined use of the fiberoptic bronchoscope and a version of the injection catheter mentioned earlier permits the injection of carcinogens in solution or suspension at preselected target sites in the bronchi of dogs and other large animals\(^3\). On later occasions the carcinogenetic process can be followed up histologically and/or visually.

Following the successful establishment of a peripheral type lung cancer model in dogs by the authors and colleagues\(^4\) (Fig. 300), it was decided to adopt this method to inject the carcinogen 20-methylcholanthrene (20-MC) submucosally at the bifurcation of the cardiac and apical lobe bronchi in beagle and mongrel dogs in an effort to induce central type lung cancer while monitoring the carcinogenetic process histologically and/or cytologically\(^4\). As the 20-MC is injected in suspension, the bore of the needle is slightly larger than that used for topical immunotherapy and chemotherapy in humans. The successful results indicate that the instrument possesses great potential in terms of experimental carcinogenesis.

The authors consider that intratumoral injections via the flexible fiberoptic bronchoscope will also assume an important therapeutic role in the future.

![Fig. 300 Carcinogenesis in dogs. The bifurcations of the right apical lobe bronchus (equivalent to the human upper lobe bronchus) of beagle dogs were injected by a special needle designed by our department for use via the fiberoptic bronchoscope to induce squamous cell carcinoma in order to examine the carcinogenetic process. The longitudinal folds of the membranous portions end abruptly and a milky white tumor protrudes forming a nodular growth. Thick folds with vascular engorgement can be seen in the apical lobe bronchus. This is one of the many cases\(^3\) of successful induction of canine lung cancer produced by the Lung Cancer Research Laboratory of the Department of Surgery of Tokyo Medical College.](image-url)