DEMONSTRATION OF A NEW GASTROSCOPE, THE "FIBERSCOPE"

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The diagnosis of duodenal ulceration by the indirect means at present available—radiology, gastric analysis, and urinary and plasma pepsinogen—leaves much to be desired in accuracy and dependability. The principle of fiber optics has been applied in the development and construction of a completely flexible optical instrument[1] which allows direct visualization of the cavity of the duodenum.

The essential light conduction takes place through a bundle, $\frac{5}{16}$ inch in diameter and 1 m. long, composed of glass fibers of hair thickness. Image transmission is accomplished by having the spatial arrangement of the fibers exactly the same at each end of the bundle, each fiber separately transmitting through its length a tiny portion of the image. The extreme ends of the fiber bundle are cemented in resin, while the rest is unbound, thus allowing extreme flexibility of the instrument.

The bundle of fibers transmits the image from a 45-degree truncated prism, set at the distal end of the instrument, through which the cavity to be examined is illuminated by a set of bronchoscope bulbs placed behind the trunk of the prism. This allows examination of the mucosa that is in contact with the instrument, since the view is at right angles to the axis of the instrument. The image is focused onto the end of the fibers by a composite lens, and a simple focusing arrangement allows one to focus from contact to infinity. The incorporation of a flexible metal sheath allows rotation of the instrument in its long axis.

The advantages of this instrument, over and above its principal advantage of enabling one to visualize the duodenal cavity, are: (1) it is completely flexible, but without image distortion, thus making it easier and safer for the patient to swallow; (2) it provides excellent light transmission, which makes photography feasible without excessive illumination; and (3) it enables one to view from contact to infinity so that the esophagus, stomach, and duodenum all can be visualized in one instrumentation.

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REFERENCE

1. Curtiss, L. E., Hirschowitz, B. I., and Peters, C. W. A long fiberscope for internal medical examinations. J. Am. Optical Soc., **46:** 1030, 1956.

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DISCUSSION OF PAPER PRESENTED BY DRS. HIRSCHOWITZ, CURTISS, PETERS AND POLLARD

Dr. Naridner S. Kapany (Rochester, N. Y.): I remember seeing Dr. Hirschowitz a few years ago, when I was in England. That was at the time when work had just been started on fibers, and I had been able to make some bundles which had qualities comparable with those which Dr. Hirschowitz has demonstrated today. It was very encouraging at that time to have somebody have the same amount of faith in the field as I had, and, knowing the problems that are involved in the fabrication of an instrument of this nature, the report by Dr. Hirschowitz at Michigan certainly is appreciated.

I am, personally, a physicist, and I am not very familiar with the clinical problem of gastroscopy. The little that I do know is what I have learned from Dr. Moses Paulson, of Johns Hopkins, and from the excellent book by Dr. Schindler.

It was in the year 1951 that my work was started in the new field of fiber optics, at the Imperial College in London. Some earlier publications had described various endoscopic applications of the fiber optics principle. Since then this principle has found diverse application in endoscopy, astronomy, refractometry, cryptography, projection systems, high speed photography, and so forth.

It might be mentioned here that some possibilities of the uses of fibers in optics were mentioned vaguely in a patent in 1927; however, no work had been reported in the field until I started work in London.

Dr. Hirschowitz put on the cap of the physicist in the earlier part of his paper in trying to describe the fiber optic principles, which I have reported in various publications, and I put on the turban of gastroscopy.

I will now try to put this principle in simple terms. I would call your attention to the use of a single transparent rod as a light pipe. As an example, when light is condensed at one end of such transparent rod, it is essentially trapped inside the rod and emerges only at the other end.

A fiber very small in diameter and of some transparent material has the same properties, with the additional advantage of almost unlimited flexibility. When a bundle of such fibers is so constructed that each fiber occupies precisely the same relative position as the two ends of the bundle, and an image is projected at one end, then the image is relayed to the other end of this bundle. This is a principle that we have called static scanning.

It can be shown that the resolution limit, or the detail that can be passed through a bundle of fibers, is essentially dependent on the fiber diameter; in other words, the smaller the diameter of the fiber, the smaller the detail that can be transmitted to the bundle.

I will not go into the details of another principle that has been described in optical circles and is known as dynamic scanning. This principle allows the transmission of detail through a given bundle of fibers, by means of a relatively simple technique.

The flexible bundles of fibers that were produced as long ago as 1952 showed high flexibility, good image quality, and light transmission. Various pictures of different types of test objects through such bundles have been published before.

Recently our group has taken some color pictures through a phantom stomach, and various outside objects have also been collected, although the color pictures taken by us show a more true color representation of the object because we used high quality optical glass for the fibers. These and the details of the complete gastroscope will appear in future publications by Kapany, Paulson, and Talbot. These activities by these workers are now going on in association with the Bausch & Lomb Optical Company.

The optics of the classic type of gastroscope allows very limited flexibility; therefore the mechanical problem of those gastroscopes did not present a great challenge. With the availability of the flexible gastroscopes the problem is posed in a different manner.

It is the purpose of Paulson, Kapany, and Talbot to construct various working models of these types of gastroscopes which will allow accurate manipulation of the instrument inside the stomach. It is hoped that it will be possible to take color pictures of the entire inside of the human stomach, including the blind areas.

To summarize the problem of fabricating such an instrument, I will just enumerate the various points that need serious consideration:

1. A flexing mechanism for the instrument which would allow it to bend at different points; (2) a rotating mechanism which will allow continuous viewing of the entire inside of the stomach; (3) an appropriate lens system for right angle and head-on view through the instrument; and (4) an illuminating system which may either consist of the conventional type of bulb at the distal end, or which may use some coarser fibers that would convey light from an outside source to the object inside the stomach.

Dr. Rudolf Schindler (Los Angeles, Calif.): Permit me to make a historical remark and to ask a question.

Dr. Hirschowitz has mentioned that the principle of glass fiber bundles was known around 1927. In fact, in 1928 or 1929, Dr. Heinrich Lamm, from Munich (now practicing in La Feria, Texas) entered my office and suggested a gastroscope based on this principle. We put bundles of glass fibers together, but we failed. I was too busy constructing what is known now as the flexible standard gastroscope. There was not yet any coating, and, most important, we lacked the advice of physicists, which here has worked so well.

The most impressive statement by Dr. Hirschowitz is that he has been able to see a duodenal ulcer, and this leads to my question.

In the last 10 years I have been interested much more in the small intestine than in the stomach. I believe, indeed, that the future of gastroenterology depends upon whether we are able to develop a method for the direct visualization of the mucosa of the small intestine. Dr. Hirschowitz has mentioned the importance of the principle in the examination of the colon; but should it not be possible to overcome the disagreeable curves of the duodenum by constructing thinner tubes, and to enter and to observe the jejunum?

Dr. Edward B. Benedict (Boston, Mass.): I should like to make a comment regarding the flexibility of the early 'scopes. One problem was produced by too flexible a 'scope and inability to rotate or properly utilize such a flexible gastroscope.

I should like to ask Dr. Schindler what his experience was with the early excessively flexible gastroscope.

Dr. Rudolf Schindler (Los Angeles, Calif.): Yes, that is true. It would be of minor importance, however, in the small intestine. Dr. Hirschowitz has indicated that a rotating mirror would make visible all portions of the mucosa; furthermore, depth of focus would not play any role in the small intestine, where one would be always at about the same distance from the mucosa.

Dr. Leonidas H. Berry (Chicago, Ill.): I have experimented with an all-flexible gastroscope and found an annoying problem of torsion. I should like to ask Dr. Hirschowitz, with reference to his new fiberscope, if he has problems of torsion of the instrument on its long axis, which may interfere with orientation or distort the picture.

Second, does this new instrument eliminate the blind spots of the lesser curvature of the antrum and the cardia?

And finally, how does he control the position of the point of the instrument so that it does not curl upon itself in the stomach?

CONCLUDING DISCUSSION BY DR. HIRSCHOWITZ

DR. BASIL I. HIRSCHOWITZ (Ann Arbor, Mich.): I should like to thank Dr. Schindler for his remarks about this work, and Dr. Kapany for some of the points he has added.

There were a couple of questions.

First of all, about orientation: this instrument incorporates in its wall a metal sheath which allows torque, so any twisting will not change its orientation.

As to the possibility of having a smaller instrument, I am sure that as the people who make these things become more proficient they should not have much trouble in making it small enough to get into the small intestine, and that is one of the most exciting prospects in the whole business. (American Cystoscope Makers, Inc., New York, are now making the instrument.) We have in fact already visualized a duodenal ulcer *in situ*.