Revista Mexicana de Cirugía Endoscópica

Volumen *Volume* **5** **Número** *Number* **2** **Abril-Junio** *April-June* **2004**

Artículo:

Resolution and magnification of the laparoscope: An observational analysis

Asociación Mexicana de
Cirugía Endoscópica, A.C.
Vol.5 No.2 Abr.-Jun., 2004
pp 104-106

Resolution and magnification of the laparoscope: An observational analysis

Jesus Flores Armenta MD,* Asif Iqbal MD,** Alexandro Elizalde Di Martino MD***

Abstract

Background: *A laparoscope is an optical instrument that allows visual examination of body cavities and internal organs that are inaccessible for direct viewing. Resolution and magnification are two of the optical properties that are important for minimal access surgeons. In principle, the resolution of the laparoscope depends on the lens's diffracting index, the magnification achieved, and the environmental light used at the moment in which the measure is taken. Regarding magnification, it is known that a higher resolution can be achieved with a higher magnification.*
Aim: *To assess magnification and resolution of a standard laparoscope through observational methods.*
Seat: *Surgical Skills Unit. Ninewells Hospital & Medical School, Scotland, UK.*
Material and methods: *Two observational experiments were carried out in order to determine the resolution and magnification of the 0° telescope. A 1 cm chart grid was used to test the magnification and resolution at different telescope-target distances. In the first experiment, which was carried out in order to determine the resolution threshold, the variables used were the distance between the image and the tip of the telescope, and the intensity of light. A photometer was used to measure the light intensity. In the second experiment, the same 1 cm square grid was used. The telescope was placed at 5, 10, 15, and 20 cm from the square grid, and the magnification ratios were obtained dividing the measures of the grid image displayed in the monitor by the real grid measures.*
Results and conclusions: *The study showed that the intensity of light that falls directly on the object being viewed through the telescope, and the magnification provided by the lens system, are both related to the telescope's resolution. The results suggest that the resolution is enhanced as light intensity increases. On the other hand, resolution increases when magnification is increased.*

Key words: *Telescope, laparoscope, Hopkins rod-lens, resolution and magnification.*

Resumen

Introducción: El laparoscopio es un instrumento óptico que permite la exploración visual de las cavidades y órganos del cuerpo humano que son inaccesibles de una visualización directa. La resolución y magnificación son dos de las propiedades ópticas que son importantes para el cirujano de mínima invasión. En principio, la resolución del laparoscopio depende del índice de difracción del lente, la magnificación obtenida por el sistema óptico y la cantidad de luz que cae sobre el objeto observado. Con respecto a la magnificación, sabemos que una mayor resolución puede alcanzarse con una mayor magnificación.
Objetivo: Determinar por medios observacionales la magnificación y resolución alcanzada por un laparoscopio.
Lugar: Surgical Skills Unit. Ninewells Hospital & Medical School, Scotland, UK.
Material y métodos: Dos experimentos observacionales fueron llevados a cabo para determinar la resolución y magnificación alcanzada por el laparoscopio de 0°. Una hoja cuadriculada de 1 cm fue utilizada para probar la magnificación y resolución del telescopio a diferentes distancias del objetivo. En el primer experimento, realizado para determinar el umbral de resolución del telescopio, las variables utilizadas fueron la distancia de la punta del telescopio al objetivo y la intensidad de la luz. Un fotómetro fue utilizado para medir la intensidad de la luz. En el segundo experimento, la misma hoja cuadrícula fue usada y el telescopio fue colocado a 5, 10, 15, y 20 cm de la cuadrícula. La medida de la imagen cuadriculada obtenida en el monitor fue dividida entre las medidas reales de la cuadrícula para obtener los cocientes de magnificación.
Resultados y conclusiones: El estudio demostró que la intensidad de la luz que cae directamente sobre el objetivo observado a través del telescopio y la magnificación obtenida por el sistema óptico, están relacionadas con la resolución. El resultado sugiere que la resolución se incrementa si la intensidad de la luz se incrementa. Igualmente, la resolución también se incrementa si se incrementa la magnificación.

Palabras clave: Telescopio, laparoscopio, telescopio Hopkins, resolución y magnificación.

INTRODUCTION

A laparoscope is an optical instrument, which allows visual examination of body cavities and internal organs that are inaccessible for direct viewing. The laparoscope consists of an optical system that carries illuminating light to the region being

* Department of Surgery, Ninewells Hospital & Medical School, Dundee, Scotland and Hospital Angeles Lomas, Mexico City.
** Department of Surgery, Ninewells Hospital & Medical School, Dundee, Scotland.
*** Department of Surgery, Hospital ABC. Mexico City.

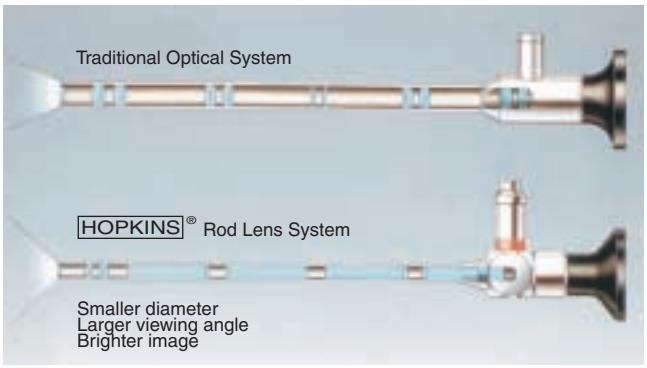

Figure 1. Traditional and Hopkins rod lens telescope. (Extracted from Storz's catalog endoscopic surgery 2nd edition 1/93).

viewed, and an optical system formed by lenses that carry the image from the region back to the eye or camera.[1] This rigid endoscope is based on the IRIL (inverted real-image lens) optical system, which creates a real and inverted image of the subject. In the Hopkins rod-lens system, light is transmitted through glass columns instead of small lenses placed at certain intervals *(Figure 1)*. These changes resulted in improved light transmission, colour definition, and image quality.[2]

Resolution and magnification are two of the optical properties that are important for minimal access surgeons. Visual resolution is defined as the ability to resolve a spatial pattern separated by a visual angle of one minute of arc. Consider that a circle contains 360 degrees. One degree contains 60 minutes. Therefore, a visual angle of one minute of arc is 1/60 of a degree. The resolution achieved by the endoscope depends not only on the endoscope's optical properties, but also on the properties of the eye or camera. In principle, the resolution of the laparoscope depends on the diffracting index of lens, the magnification achieved, and the environmental light used at the moment in which the measure is taken.

Regarding magnification, it is known that higher resolution can be achieved with higher magnification. Magnification relates to the apparent size of an object as the eye observes it. Since the apparent size of an object varies depending on the angle that the object subtends at the front focal point of the eye, some arbitrary choice of distance must be made in order to define visual magnification. For the case of nearby objects viewed by an endoscope, the viewing distance adopted is 250 mm. Thus, visual magnification is defined as the ratio of image size to object size, when the image is positioned 250 mm from the eye. For rigid telescopes, this magnification is given by the product of the linear magnification of the objective (m0) and the visual magnification of the eyepiece (me). Commonly, the product M= m0 me is near unity.[1,3]

An analysis based on wave optics indicates that the detail that can be resolved by the eye is limited by the diffraction patterns produced by the pupil. It is known that the resolution of the average eye is approximately 0.10 at 250 mm. Thus, if the endoscope magnification is M, a viewer with normal vision can resolve 0.10/M mm. Nevertheless, as the distance of an object increases, the distance between the image and the eye also increases, and visual magnification and resolution are reduced. The highest resolution is obtained when the object is at a distance from the objective, which produces an image at the near point of the eye. In other words, the highest resolution is achieved when the image is in focus.

In order to assess resolution and magnification of the telescope, observational experiments were carried out with the aim of finding the telescope's magnification and resolution by changing the telescope-target distance and the light intensity. As stated before, magnification is strongly related with resolution, thus this will allow us to determine the resolution of the telescope.

MATERIAL AND METHODS

Two observational experiments were carried out in order to determine the magnification and resolution of the 0° laparoscope. A 1 cm square grid chart was used to test the magnification and resolution at different telescope-target distances. The grid was divided into 100 tiny 1-mm squares and placed inside a trainer box. In the experiment carried out in order to find the resolution threshold of the telescope, it was placed in the holder arm. The 450 V xenon cold light source was set up at 5%, and the intensity of light was measured with a photometer. Then, the researchers moved the telescope to the farthest distance at which the image viewed by the eyepiece of the telescope could be resolved. The distance between the tip of the endoscope and the grid was measured with a common ruler. The same was done changing the light intensity of the light source to 55% and 95%.

The second experiment was carried out in order to determine the magnification of the laparoscope. The same 1 cm square grid was used in this experiment. The telescope was placed at 5, 10, 15, and 20 cm from the square grid. The grid was displayed into the monitor and then measured for each telescope distance. The magnification ratios were obtained dividing the measures of the grid image displayed in the monitor by the real grid measures. In the test, the camera's zoom remained a constant.

RESULTS

Table 1 shows the resolution threshold of the telescope with different light intensities. The differences that were obser-

Table 1. Resolution threshold of the telescope with different light intensities.

Subject	Light intensity	Photometer	Distance
1	5	0.57 mV/cm^2	23.5 cm
1	55	1.84 mV/ cm^2	27.5 cm
1	95	2.16 mV/cm^2	31.1 cm
2	5	0.57 mV/cm^2	17.1 cm
2	55	1.84 mV/ cm^2	19.3 cm
2	95	2.16 mV/cm^2	21.5 cm

Table 2. Resolution in relation to telescope magnification.

0° Telescope target distance	Magnification Ratio TV monitor	Telescope resolution (mm)
5 cm	6	0.01
10 cm	3.3	0.03
15 cm	2.2	0.04
20 cm	1.75	0.05
33 cm	1	0.10

ved in the achieved resolution between the two researchers are expected, because normal differences in visual acuity exist between subjects.

Table 2 illustrates the results of telescope magnification in each position. The ratios were obtained dividing each measure obtained at the different positions by the original measure. Therefore, following the equation of resolution 0.10/M mm, the telescope can resolve at 5 cm 0.10/6 mm, at 10 cm 0.10/3.3 mm, at 15 cm 0.10/2.2 mm, at 20 cm 10/1.75 mm, and at 33 cm 0.10/1 mm.

DISCUSSION

The laparoscope is the eye of the laparoscopic surgeon; therefore, it is important to count on a high quality telescope. When examining a telescope's quality, one should determine its resolution, depth of field, optical light transmission, viewing angle, and chromic aberration.[4] Since the telescope is built with a lens, the laws of optics limit its resolution.[5] In other words, the telescope is the product of the quality of the lens used in its construction and the wavelength of light used in its measurement. Moreover, magnification is also linked with resolution.[1]

The study showed that the light intensity that falls directly on the object being viewed through the telescope, and the magnification provided by the lens system, are both related to the telescope's resolution. The results suggest that the resolution is enhanced as light intensity increases. On the other hand, resolution increases when magnification is increased. The results also illustrate that the resolution of the telescope is similar to the resolution of an average normal eye. In fact, the resolution of the telescope is not a problem at the moment, because video chip cameras currently used in minimal access surgery have lower resolution than telescope optics.[2]

The resolution of the telescope was tested in an empirical way. However, the true resolution of the telescope can only be proved by using the formulas provided by the physical laws of optics. Diffraction, lens aperture diameter, and light wavelength have to be taken into account in order to determine the resolution of the telescope. This study cannot be carried out in a scientific way because a device that measures the wavelength of light cannot be obtained. However, the results of this experiment give us a good idea of the resolution and magnification achieved by standard telescopes used in minimal access surgery.

REFERENCES

1. Gardner FM. Optical Physics with Emphasis on Endoscopes. *Clin Obstets & Gynecol* 1983; 26: 213-218.
2. Meltzer A, Buess G, Cuschieri A. Instruments for endoscopic surgery In: A. Cuschieri, G. Buess, J. *Perissat, Operative Manual of Endoscopy Surgery 1*, 1992, Springer-Verlag, Berlin, Germany.
3. Boppart SA, Deutsh TF, Rattner DW. Optical imaging technology in minimally invasive surgery. *Surg Endosc* 1999; 13: 718-722.
4. Paz-Partlow M, Berci G, Practical camera evaluation: a review of principles. *Min Invas Ther & Allied Technol* 1996; 5: 445-9.
5. Holmes JB. Study Guide: Light II In: Physics III *[http://www.cbu.edu/jholmes/P252/intro.html]* (20-08-2001).

Correspondence:
Jesus H. Flores Armenta MD
Av. Vialidad de la Barranca S/N,
Suite 270. Col. Valle de las Palmas,
Huixquilucan, Edo. México. C.P. 52763.
Hospital Ángeles de las Lomas
Telephone: 52465000 ext. 4270 - 4271