

# Initial Experience of 3-D Video Endoscopy in General Surgery

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The worldwide explosion of laparoscopic surgery within general surgery began in the late 1980s and early 1990s. From its inception, surgeons have expected the image on the video monitor to resemble closely the image obtained in similar open surgery. The monitor image, however, is presented in two dimensions—height and width. Orientation of the surgeon to the anatomy is more difficult and requires a sound knowledge of anatomy, the relationships of organs to each other, and an understanding of the individual patient's unique structures. Adding a third dimension, depth, to imitate natural vision in open surgery may provide surgeons with the confidence to perform more advanced procedures. In addition, trainee surgeons, without the experience of open surgery which their senior colleagues have gained, may more rapidly appreciate orientation of the anatomy and learn the surgical task more quickly.

## PATIENTS AND METHODS

During a 10-week period, 21 patients were operated on using the 3DConverter system (International Telepresence, Vancouver, B.C.) (Table 1). There were 8 male and 13 female patients. The age range was from 23 to 74 years with a median age of 52.2 years. The surgery was performed by the consultant surgeon in 15 cases and by an experienced surgical trainee under the direct supervision of a consultant in 6 patients. Two junior surgical trainees each

performed part of one operation.

Once pneumoperitoneum (or pneumothorax) was created, a visual inspection with the laparoscope confirmed the success of this part of the procedure and the 3DConverter was attached to the camera and laparoscope. The total operative time using 3-D was 29.5 hours. The range of time using 3-D was from 40 minutes to 120 minutes with a median time of 84 minutes.

The camera system used was a Stryker 597 single chip camera. The light source was a Storz Xenon 300.

The endoscopes used in this specific study were 10-mm laparoscopes of various brands (including Wolf and Olympus); however, 4-mm cystoscopes and arthroscopes have been used with this system, and surgeons from other disciplines (orthopaedics, gynecology, and urology) within our hospital have worked successfully with the system (not reported here).

Before equipment was used, it was all thoroughly tested in the laboratory and met the appropriate safety standards. Earth leakage and continuity were tested

in accordance with hospital requirements and the equipment passed all tests.

**RESULTS**

Our initial experience using this system has been very encouraging. The image projected has been of a very high standard and 3-D is readily perceived during the operation. In no operation was the 3-D turned off in favor of conversion to two dimensions to complete the surgery. No member of the surgical team or anesthetic staff, nor theater nurses or any observers complained of nausea or headache as a result of watching in 3-D.

Trainees have reported that they have found video endoscopic surgery much easier to follow when it is demonstrated in three dimensions rather than two dimensions. They have also found it easier to perform the surgery, particularly the junior surgeons. Although we have not formally tested it, we believe that the frequency of instrument hunt which the surgeons use to gauge depth is reduced.

A major advantage of this system when using 3-D mode is that theater nurses and anesthetists who do not need to follow the operation in 3-D (and perhaps do not wish to wear the 3-D glasses) can follow the procedure very easily on the video display unit. There is some very slight blurring of the image around the edges but the scrub nurse can comfortably watch the operation and anticipate accurately the surgeon's requirements for instruments. Similarly the anesthetist can also follow the operation and at the same time watch the various anesthetic monitors during the case.

In advanced laparoscopic procedures, the use of 3-D in our early experience has given the surgeon more confidence when performing technically difficult procedures, including, for example, mobilization of the esophagus or of the rectum. The 3-D is particularly noticeable when operating in narrow confines such as in the pelvis or the esophageal hiatus. In addition, when repairing an inguinal hernia, it is easier to identify the relationship of the crease of the mesh and to apply the mesh smoothly to the posterior inguinal canal.

Video recordings can be made of the procedure using standard video recording equipment. These videos can be played back in either two dimensions when carrying out a crude edit, or in three dimensions using the Telepresence system.

We have not found the 3-D glasses uncomfortable or heavy to wear. Some members of the surgical team have chosen to

OPERATIONS PERFORMED	Number
Cholecystectomy +/- on-table cholangiogram	14 (5 with on-table cholangiogram)
Inguinal hernia, bilateral or recurrent	5 (2 bilateral)
Nissen fundoplication	1
Synchronous combined abdominoperineal excision of rectum	1
Thoracoscopic sympathectomy	1
Division of adhesions	1

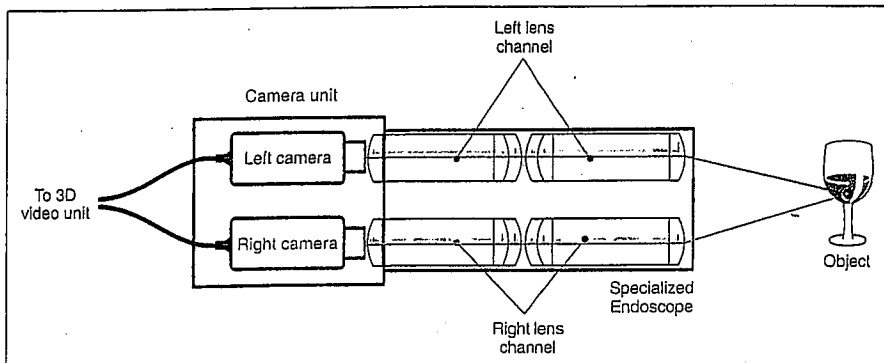


Figure 1a. Dual camera/dual optical channel 3-D system.

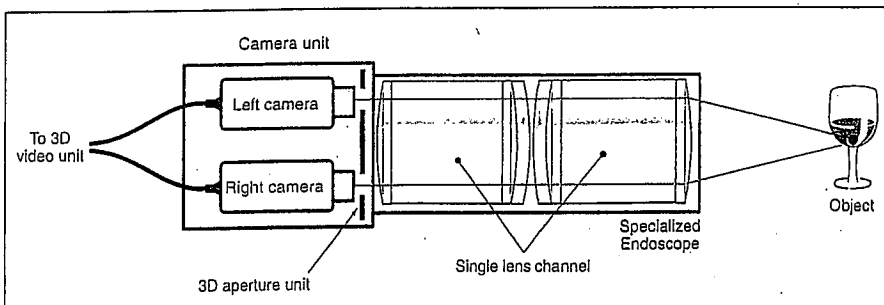


Figure 1b. Dual camera/single optical channel 3-D system.

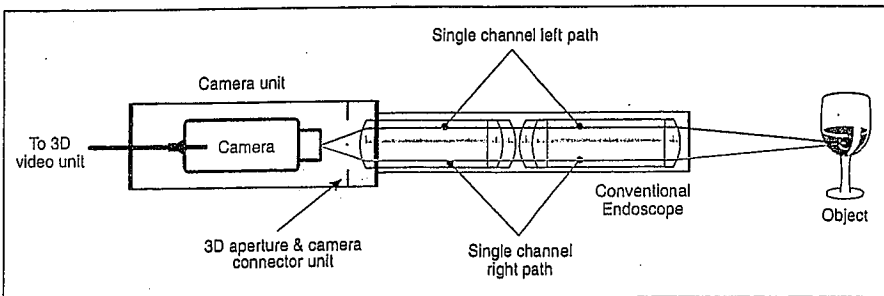


Figure 1c. Single camera/single optical channel 3-D system (Telepresence).

put the glasses on before scrubbing up, others have preferred to have the glasses placed on the head once the procedure is under way. Once wearing the glasses, fluorescent theater lights must be turned off and anesthetic video display unit monitors must be turned away from the surgeons, as flickering from both sources is a distraction. Theater nurses and anesthetists have taken to using dimmed but adequate light-

ing around their sphere of work without interrupting the surgeon's concentration.

**TECHNICAL DISCUSSION**

Our perception of the environment in which we live is based upon well described and understood sensory input. The brain interprets a variety of stimuli upon which we base our concepts of the physical

world. When performing a complex task such as a surgical operation, the two most important inputs are sight and touch. In open surgical procedures, there is a wealth of tactile and visual stimuli. In laparoscopic surgery many of these subtle stimuli are removed, and the surgeon must operate with 2-D vision and tactile sensation transmitted to his or her hands through long, thin instruments. Three-dimensional systems have been developed to return some of these inputs to the surgeon.

Until recently, 3-D developers believed that two cameras were required to emulate natural vision with two eyes. These systems always contained two cameras and invariably had two optical channels through specialized scopes (Fig. 1a). A more recent design uses a specialized scope with a single optical channel and two cameras (Fig. 1b).

The Telepresence system (Fig. 1c) differs from these initial approaches by using the single optical channel that exists in conventional rigid endoscopes. By placing a special optical converter at the eyepiece of the endoscope and connecting to only one camera—either single or three chip (Figs. 2, 3)—the Telepresence add-on produces true stereopsis. The 3-D image is not motion-dependent, nor is it digitally created.

The 3-D converter extracts a true stereo pair of images from the endoscope which are then presented on a high speed monitor, with an infrared emitter synchronizing the shuttering of a pair of 3-D viewing glasses, creating a 3-D image in the brain.

There are several practical and ergonomic advantages offered by this single camera and optical channel system. The system requires only one camera (NTSC or PAL)

and this can be changed or upgraded as conventional camera technology develops. The system can be attached to most rigid endoscopes in general use by a variety of surgical disciplines, including angled scopes (e.g., 30° laparoscope or arthroscope) from 1.9 to 12 mm.

This elimination of dedicated cameras and scopes from a 3-D system means that there is significant simplification in the system, with resulting savings in cost, size, and weight.

There are however, important technical advantages to the single camera/single channel approach to 3-D endoscopic vision.

### Natural Vision

The closer that we can emulate human natural vision for seeing 3-D, the more likely one will be able to create a comfortable and practical 3-D image. In natural vision, we see two slightly different views of an object, one from each eye; the brain then processes these images to provide 3-D perception.

When looking at an object, our eyes converge on the object and resolve the image pairs into a single image (Fig. 4a). At the same time, they automatically focus on the object. The natural convergence and focusing capacities of our eyes are always linked and work in the same plane.

If focus and convergence are not linked, the brain must make considerable effort to process the image. One such example is viewing the popular 3-D posters. The eyes are required to diverge for distance viewing, but at the same time focus on a point far closer in order to perceive the 3-D image (or alternately converge the eyes strongly [cross eyes] and focus behind this point). Both methods of view-

ing are unnatural because the eyes are forced to unlink convergence from focus, requiring considerable effort on the part of the observer. Although the brain can deal with this biological insult in the short term, eye strain is evident over time.

### Dual Camera vs. Single Camera Systems

Conventional dual camera systems (Figs. 1a-1b) have preset convergence and most have preset focus because of the complexities involved in maintaining alignment and equal magnification of the two optical pathways. It has been observed that "accommodation (i.e., focusing of the eye) and convergence (i.e., inward rotation of the eyes to view near objects) cues, important aspects of normal viewing, cannot be duplicated in present systems" using two cameras. This creates a series of difficulties. Users of dual camera/dual lens endoscopic systems have often experienced visual distress in the form of fatigue or occasionally headaches and nausea. Any imbalance or microvariation in any parameter (magnification, alignment, etc.) between the two optical paths will be compounded and contribute to eyestrain. The single camera/single channel system (Fig. 3) creates identical image pairs differing only in parallax, which are exactly aligned over the entire range of focus. Any microvariations are common to both eyes. This reduces eyestrain and the effort required by the brain to process the images.

Preset convergence and focus also lead to another problem. There is only one position in front of the endoscope where both convergence and focus are matched. Objects in front of and behind this optimal position will have focus and convergence mismatched, resulting in the same viewing

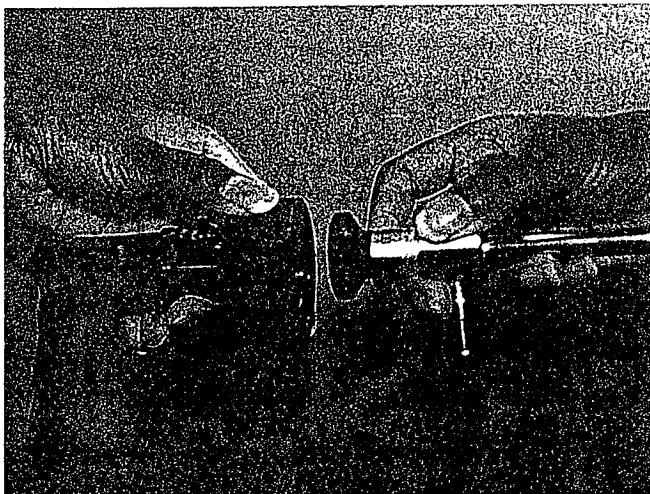


Figure 2. 3-D converter with single-chip camera.

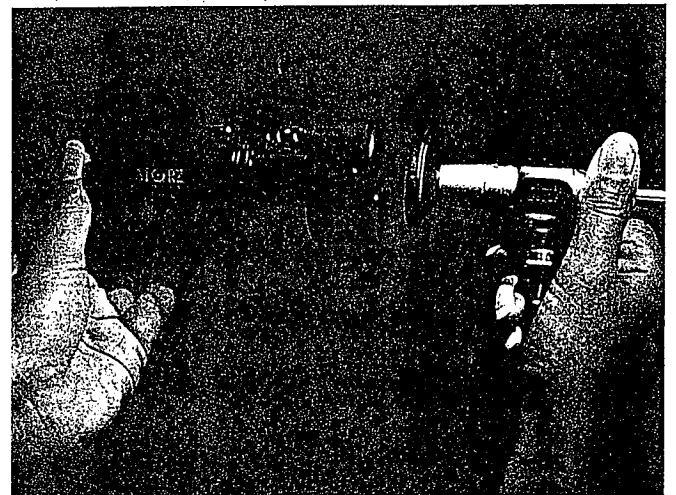


Figure 3. 3-D converter with three-chip camera.

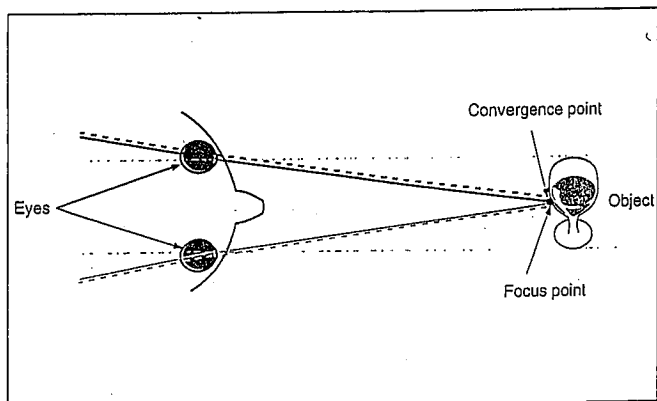


Figure 4a. Natural vision: linked convergence and focus.

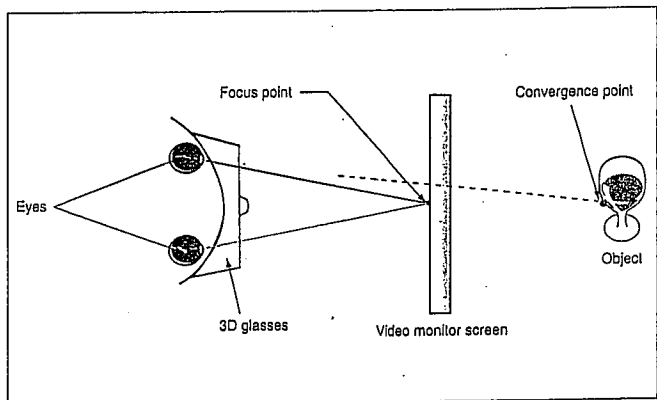


Figure 4b. Dual camera systems: mismatched convergence and focus.

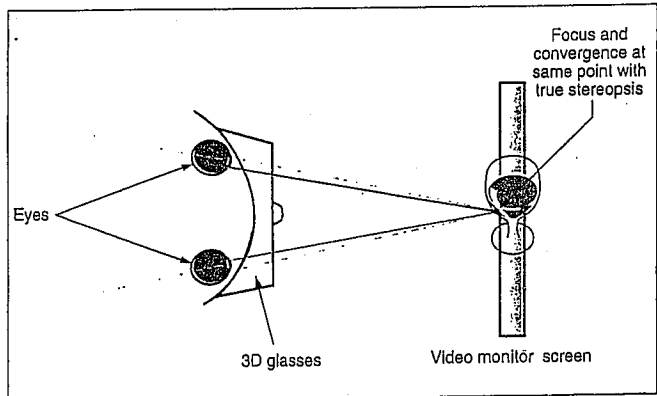


Figure 4c. Single camera (Telepresence) system: linked convergence and focus.

problem as 3-D posters (Fig. 4b). Since focus and convergence are no longer linked as the brain expects, eyestrain and fatigue result.

A single camera system (Fig. 4c) maintains linked focus and convergence as in natural vision, and avoids eyestrain. In addition, it allows the image displayed on the monitor to be viewed normally without glasses (Fig. 5), while those with glasses see the same image in 3-D. Dual camera systems currently do not permit this.

The human eye naturally focuses on one plane at a time, with other planes out of focus. This can be demonstrated by

holding two fingers in front of you and focusing on the one further away; the front finger is then out of focus. In the Telepresence system, anywhere outside the focal point, the images remain out of focus, almost exactly mirroring the action of the human eye and better resolution than 2-D optics, and did not appear to compromise field of vision, color or light as compared to 2-D. The degree of 3-D delivered by the system is dependent upon the visual acuity and brightness of the scope, with scopes having a wide distal aperture delivering the best 3-D.

brain. The point of focus is always the point of convergence. In practical use, the depth of focus is sufficient for working depth, with focus adjustments rarely required during surgery. With dual camera systems, there is a very large depth of focus because of the very small diameters of each optical channel, which initially provides the viewer with a dramatic perception of 3-D. Over time, however, this can cause fatigue as the eye cannot easily find the natural point of matched focus and convergence within the image without a great deal of concentration and effort.

This system seemed to deliver equal or

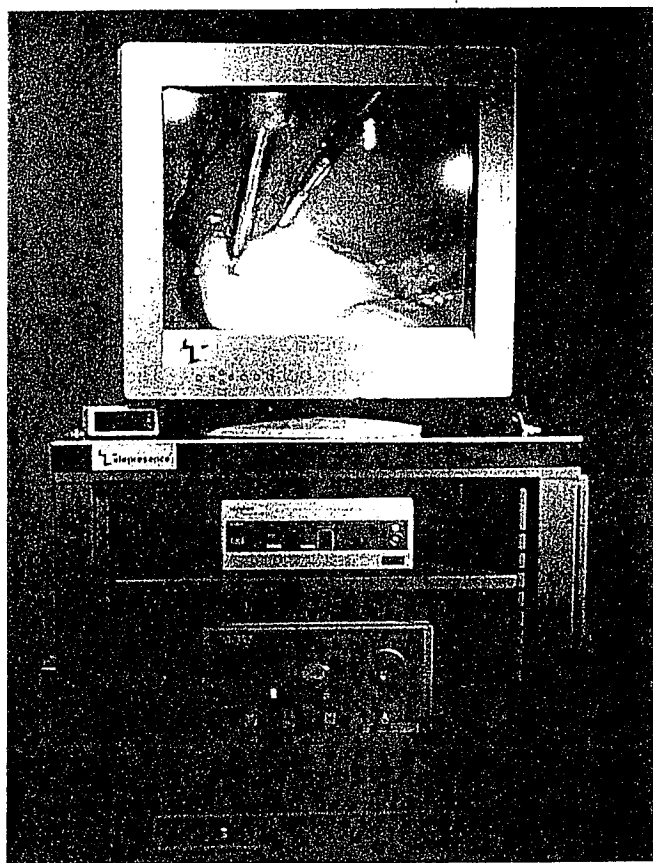


Figure 5. Three-dimensional image is clear without glasses.

## DISCUSSION

Within our limited experience of using the 3-D converter, it is not possible for us to draw any conclusions that the 3-D system has any measurable advantages over the 2-D alternative. For example, comparing our operative time for laparoscopic cholecystectomy without on-table cholangiography, there has been no significant improvement in the time taken when compared with our performance using a 2-D system. However, this is not surprising, as laparoscopic cholecystectomy has been the procedure of choice for symptomatic gallstones in this unit for 5 years and is the most common laparoscopic procedure performed here. Surgical trainees with limited experience of open surgery much prefer to watch and operate using the Telepresence 3-D system. Whether this is the result of the preference for 3-D or other factors which contribute to an

improved image requires further evaluation. Others have found that 3-D provides a 25% improvement in time for procedures,<sup>2</sup> and a statistically significant improvement in knot-tying tests by experienced surgeons.<sup>3,4</sup>

Based on our early experience with this system, we have found it to be safe, robust, and reliable. Because this technology imitates the process of natural vision, the problems of eyestrain, nausea, and headaches have not been encountered. The preference and enthusiasm for using this 3D Converter system expressed by our

surgical trainees has led us to believe that this system will be most widely used in specialist minimally invasive surgical units with a large commitment to training. Furthermore, together with other technological advances in laparoscopic surgery, we believe that this system will contribute to the development of new concepts within this nascent branch of general surgery. **STI**

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