Surg Endosc (1988) 2: 167–171

Surgical Endoscopy

The impact of electronic imaging in intraoperative biliary endoscopy (choledochoscopy)*

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Summary. In the last decade, choledochoscopy has become an essential tool for biliary surgery. It is widely accepted, but it is not employed by every surgeon who performs choledocholithotomies. The reason is the limited experience of surgeons performing 30–40 cholecystectomies per year. A survey of 150 hospitals clearly showed that common bile duct exploration is performed in 10%–15% of these cases. General surgeons are not endoscopists. A new video choledochoscope that displays the image in a large format via the TV monitor was developed, which can be viewed with both eyes and an assistant's help; this expedites and coordinates the procedure. The entire process is videotaped and can be used for further analysis and during consultation. It has become the method of choice for teaching. Most importantly, the learning curve of general surgeons has become significantly shorter. The procedure is taught and the surgeon can learn it easily. Its use will contribute to a decrease in the incidence of retained stones and will improve patient care.

Key words: Electronic imaging – Choledochoscopy – Video choledochoscopy.

In the United States, 500,000 cholecystectomies are performed per annum. In 10%–20% of these (depending on the age of the patient), the common bile duct needs to be explored. Approximately 75,000–80,000 choledochotomies are done annually. The real incidence of retained (missed) stones is not known. It can vary from 5% to 20% [3, 10].

Unsuspected stones occur in 5%–10% of operations [4]. In this report, we are referring to patients with no clinical signs or symptoms of choledocholithiasis. A real figure for this group is difficult to assess because this type of common bile duct stone is *only detected* when a proper, *routine cholangiogram* is performed. We strongly recommend routine, operative cholangiography because at the early stage of operation, it is advantageous to know the anatomy, the location of stone(s), anomalies of surgical importance and the appearance of the sphincter. Many unnecessary common bile duct explorations and iatrogenic injuries could have been avoided, if this recommendation had been followed. Modern fluorocholangiography with serial films avoids unnecessarily long operating times and provides higher diagnostic accuracy [6].

Exploration of the common bile duct

Courvoisier and Kehr described the technique of common bile duct exploration around the turn of this century [11, 13]. The technique today, however, is similar. We introduce stone graspers, spoons, probes or balloon catheters *blindly* and manipulate for a prolonged period of time until the stone is recovered.

The advantages of a visual technique were discovered by Bakes as early as 1926 [1]. Wildegans introduced a modified cystoscope (choledochoscope) and claimed a high success rate [18].

* Based on a presentation to the International Congress on Surgical Endoscopy, Ultrasound, and Interventional Techniques, Berlin 1988

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One of us (G. B.) introduced this method 27 years ago, but the initial results were not very encouraging [2]. The invention of a new optical system by Hopkins helped us to develop a right-angled rigid choledochoscope 18 years ago, which was easy to manipulate and produced a superb image [10]. At a later stage, flexible scopes were introduced, which could be employed for intra- and post-operative choledochoscopy [8, 19].

Intraoperative biliary endoscopy (choledochoscopy) has been accepted by the majority of surgeons and is now a well known adjunct for common bile duct surgery. Analyzing the clinical results, we found two extremes: some institutions report an incidence of missed stones after choledochoscopy as low as 1%–2% while others still have 6%–9% retained stones after the use of intraoperative biliary endoscopy [8, 12, 15]. However, everyone who employs the scope agrees that after standard extraction maneuvers are completed and the endoscope introduced, stones were discovered *in 10%–15% of cases* that otherwise would have been missed [7].

We took a survey in 150 hospitals and found that 85% have rigid or flexible instruments available in the operating rooms. However, only 8% of the surgeons use them routinely during explorations [17]. A similar report has been published by other authors [14]. This fact clearly indicates that the general surgeon is not well acquainted with choledochoscopy because he is not an endoscopist. The factors involved are the extended learning period, a lack of case material, and therefore limited experience. It is also known that if we are working in an extremely well-illuminated operating area for 1–1.5 h to dissect a difficult common bile duct, and then we introduce a choledochoscope through the incision, we suddenly have to change over from an extremely bright area to the small, dim pupil of a monucular eyepiece. *It is difficult to adapt visually and perceive changes in appearance in this short period of time.*

Certain questions still remain to be answered: How can the general surgeon become more familiar with this procedure? How can choledochoscopy be taught more easily? How can a surgeon learn to practice it in an easier way?

Animal model

It is possible to use an animal for an experiment on an acute condition and dissect the vena cava below the renal veins. The tail veins and lumbar veins must be ligated. A tubular system is created where choledochoscopy and stone removal manipulations can be practiced. This dissection takes approximately an hour or so, but unfortunately not every hospital has the facilities. Furthermore, this acute experiment is not inexpensive.

Biliary model

There are many models available, but they are made of rigid materials and do not represent the features with which we are confronted during surgery. We designed a biliary model where the surgeon and the assistant can practice using irrigation (Gaumard Scientific Co., Coral Gables, Fl.). The duodenum must be kept stretched in order to improve vision of the sphincter area. It is worthwhile setting aside an hour or so to practice with a colleague in order to become more familiar with the instrumentation and the various tricks of the trade [5].

Over the years, we have learned two important lessons: (1) teamwork and (2) improved vision.

Teamwork

We really need four hands to perform choledochoscopy and the stone-removal process properly. The duodenum should be mobilized. With one hand, the surgeon keeps the distal duodenum on a stretch (which is a very important maneuver), while the other hand holds the scope. Here, a trained assistant who can coordinate his/her movements with those of the surgeon could be immensely helpful. The operator is engaged with the thumb at the lever of the control handle that provides the movement of the tip of the instrument. The assistant advances or withdraws the stone-manipulating instrument (basket, stone grasper or balloon catheter) when necessary. If the stone is located, the operator maintains the position and the assistant entraps the calculus, with the basket or balloon introduced through the instrument channel. It is important to avoid repeated movements, which can cause oozing and interfere with vision. The best opportunity is the first one. The assistant's training and knowledge about the technique is just as important as that of the surgeon.

It is worthwhile starting in the proximal (hepatic) part because there is less inflammation (cholangitis), and the anatomy itself permits easier orientation. If a red or yellow disc is seen, this means that the tip of the scope is touching the wall. The assistant at this stage slowly withdraws the scope and the lumen will suddenly come into view. If the assistant slowly advances the scope towards the orifice, the operator can move the tip up or down. The lumen should always be kept in the middle of the visual field. *Slow movements are essential.* There are great anatomical variations in the proximal duct between the various orifices, which can easily be identified. In the elderly patient with dilated ducts, biliary mud and innumerable small facetted calculi in the extrahepatic biliary system, it is worthwhile considering an enterobiliary anastomosis. It is very difficult to evacuate a large number of stones from the proximal ductal system. Choledochoscopy can help in the decision making.

Turning the scope distally, the operator (who should stand on the left side of the patient during biliary endoscopy) exerts a pulling action on the mobilized duodenum with the left hand; the tortuous distal duct will be straightened and vision is improved. The thumb is on the lever that controls the tip movement. The assistant introduces it into the incision, checks the irrigation, and provides a torque if necessary. The distal duct is technically more difficult to examine than the proximal duct.

Improved vision

The evolution in electronic imaging systems has created small television cameras, weighing only 60 g, which can be attached to the eyepiece of the choledochoscope and sterilized together. It is of great advantage *to observe conveniently with both eyes an enlarged image* instead of looking into a small, dim monocular eyepiece. To perceive smaller details or functions becomes easy because the image is *magnified.* The assistant's movements are *coordinated* and the entire team can follow the procedure [9].

Time is not wasted for adaptation and the procedure is more accurate and faster. If a stone is discovered, the most important hint is to avoid unnecessary movements that can interfere with vision. The stretched distal duct position is maintained and the assistant advances a basket or balloon catheter according to the need. After the stone is entrapped, both the surgeon and assistant withdraw the choledochoscope, together with the stone into the incision.

The function of the sphincter has never been as well observed and assessed as recently, using the video choledochoscope connected to a videotape recorder. If this area can be observed for a minute or so, one can distinguish between the edematous, inflamed folds of the distal duct and the actual sphincter. If you clearly see the distal common bile duct and the sphincter area, you can be assured that the duct is free of stones. If, for one reason or the other, this particular anatomical area cannot be seen well due to inflammation, edema, or a sharp distal flexure, a French 4 (vascular) balloon catheter is advanced *through the instrument channel* and is passed, under televisual control, towards the duodenum. The assistant inflates the balloon, and the position in the duodenum is checked by palpation. During withdrawal of this inflated balloon *with the choledochoscope in a stationary position,* you can see how the inflated balloon is pulling the *actual sphincter area towards the scope.* If the assistant slowly deflates the balloon and pulls it towards the scope, the entire team can identify the entrance of the partially deflated balloon into the common bile duct, clarifying the anatomy. In case of tumors (very rare), a biopsy forceps can be advanced and tissue samples can be obtained. Tumors in the head of the pancreas cause external compression. No final conclusion can be drawn from this appearance.

A very important adjunct in video choledochoscopy is the possibility of having a simultaneous videotape recording available at the surgeon's elbow or at a later stage during consultation, as it can be analyzed in questionable cases. Furthermore, a better understanding of the sphincter function can be obtained. *Video choledochoscopy has become the method of choice in a teaching program.* For the general surgeon who is not an endoscopist, this new procedure is much *faster to learn and easier to perform* because of the significantly improved visual conditions.

Results

At our institution we perform approximately 300 cholecystectomies with a common bile duct exploration rate in 40–45 cases per year. Before the intensive use of choledochoscopy, the missed stone incidence was 12%. During the past 6 years, it decreased to 2%–3% per year, after the majority of surgeons had begun to use it routinely (Fig. 1).

The number of enthusiastic operators increased significantly after introduction of video choledochoscopy. Surgeons, assistants, and house staff were trained and became acquainted with the technique after a 2-h seminar. In interesting cases, the video tape recording is scrutinized by the operators, radiologists, and residents in training. The learning curve has become shorter and the interpretation of findings much easier. It is hoped that in the next few years our results will improve even further.

We use the flexible scope attached to a TV camera because we employ the same instrument

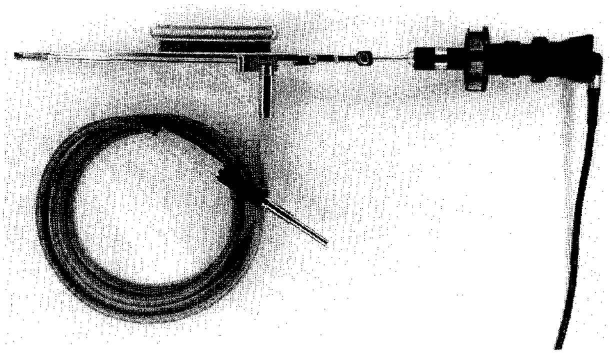

Fig. 1. The rigid right angled choledochoscope with an attached television camera (Karl Storz Endoscopy of America, Inc.)

in the post-operative period, through the T-tube tract if a retained stone is discovered. Every endoscopic procedure has benefited from the introduction of the video technique (Fig. 2).

Documentation is important, but unfortunately the use of still or movie films caused problems (time delay, processing, identifying the patient, etc.) and was a burden to the operator and nursing staff. We never knew the final outcome in advance. In television, however, the immediate display gives us an idea of the image quality to be recorded. There is no interruption or interference with the routine if the procedure is televised because the entire process is observed and simultaneously recorded.

A videotape can be analyzed or scrutinized later. It is of great value in evaluating the findings for consultations, presentations, or teaching. We are expecting more improvements in the field of frozen (still image) pictures, video disc storage, and electronic color thermal printers in the future.

Video choledochoscopy has already proven its significant advantages compared with the standard endoscopic approach. The video technique is more suitable for the general surgeon. At this stage, we are using the standard, flexible choledochoscope attached to a 2/3 in. video (chip) camera, weighing only 60 g. The entire instrumentation is gas sterilized or can be soaked. Every item is mounted on a cart and can be moved from one operating room to another. We have found this new technique to be extremely useful and, hopefully, we can encourage more surgeons to use it routinely when intraoperative biliary endoscopy is required (Fig. 3).

Discussion

Choledochoscopy was introduced two decades ago. It became an important intraoperative diagnostic modality in biliary surgery. Practice, experience, and familiarity with the instrumentation are important factors in any endoscopic procedure. In general, the problem with biliary surgery is that if a surgeon performs 30 cholecystectomies per year, the number of choledochotomy cases is no greater than 3–5 cases/year. Therefore, the opportunity to employ biliary endoscopy is limited. Choledochoscopy inherited another problem, namely, the sudden change to a small, dim, monocular image from a well-illuminated area, which makes adaptation difficult. Another limitation of this process is perception, which is dependent on many factors including the image quality. If the image is very small and not bright, extreme concentration is required to look through the small pupil of an eyepiece. The surgeon may find it difficult to visualize the object. In general, monocular vision decreases depth of field and perception.

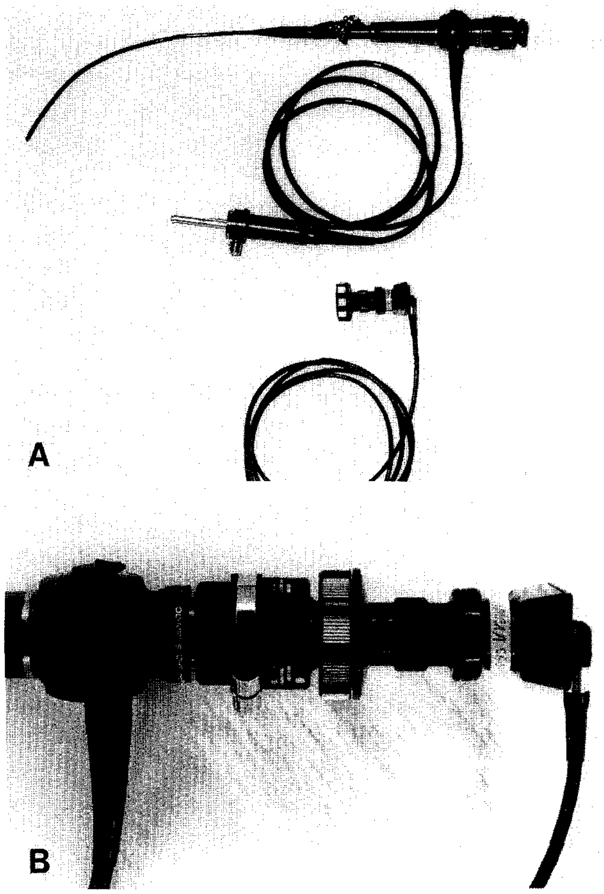

Fig. 2. A The flexible choledochoscope (Olympus, New York) is sterilized together with a miniature 2/3 in chip camera attached. **B** Close-up. The camera is coupled to the choledochoscope by means of an eyepiece adaptor

Television has become an ideal solution for endoscopy because the image is *enlarged*, can be

Fig. 3. The operator and assistant can see the enlarged image from a convenient distance, and therefore manipulations and coordinated movements become easier, resulting in a faster procedure. A simultaneous videotape recording is obtained for analysis. Interesting or unusual sphincter function can be observed clearly (see text for details)

seen by *both eyes*, no significant adaptation is required, and perception is facilitated. Choledochoscopy and stone removal require teamwork. This is a "two-person" job. Therefore, coordination of the assistant's movements is crucial. As soon as the stone is in position, the assistant introduces a stone-manipulating instrument through the choledochoscope. The stone is entrapped in a coordinated fashion and withdrawn into the incision. Choledochoscopy is difficult to teach, but not with the use of television. This is another reason why this procedure has become the method of choice.

Observation of the sphincter is of great interest. The opening and closure can be well observed. In the presence of edema, cholangitis, or difficult anatomy, a French 4 balloon catheter can be advanced through the instrument channel into the duodenum, and the inflated balloon is withdrawn. We can see clearly where the sphincter area is located. Furthermore, if the assistant deflates the balloon, one can see where the deflated balloon traverses the sphincter area to avoid any missed stones. Conversely, if a Fogarty French 5 balloon catheter using the standard (blind) technique is advanced into the duodenum, withdrawn and deflated, it will suddenly "jump" through this area. There is always the possibility that a stone will be missed. However, with a visually controlled technique, this can be avoided.

Another interesting aspect is the complex anatomy of the superior and inferior sphincters, which can be seen as separate entities. In several cases where these two sphincters *were apart*, using the television technique and analyzing the tape, both sphincters were easily identified. The simultaneously obtained video recording is of utmost importance. We have never been able to recognize these areas so clearly nor have we been able to give an explanation of this phenomenon before.

References

1. Bakes J (1923) Die Choledochopapilloskopie. Arch Klin Chir 126: 473–483
2. Berci G (1961) Choledochoscopy. Med J Aust 2: 861–863
3. Berci G (1981) Incidence of retained stones. In: Berci G, Hamlin JA (eds) Operative biliary radiology. Williams & Wilkins, Boston, pp 7–12
4. Berci G (1981) Unsuspected stones. In: Berci G, Hamlin JA (eds) Operative biliary radiology. Williams & Wilkins, Boston, pp 7–12
5. Berci G, Cuschieri A (1987) A biliary endoscopy model. Am J Surg 153: 576–578
6. Berci G, Hamlin JA (1981) Critical analysis of fluorocholangiography. In: Berci G, Hamlin JA (eds) Operative biliary radiology. Williams & Wilkins, Boston, pp 203–213
7. Berci G, Paz-Partlow M (1984) Operative biliary endoscopy (choledochoscopy) in common bile duct exploration. In: Cuschieri A, Berci G (eds) Nijhoff, Boston Dordrecht, pp 55–59
8. Berci G, Hamlin JA, Grundfest W (1983) Combined fluoro-endoscopic removal of retained stones. Arch Surg 118: 1395–1398
9. Berci G, Shulman AG, Morgenstern L, Paz-Partlow M, Cuschieri A, Wood RA (1985) Television choledochoscopy. Surg Gynecol Obstet 160: 176–177
10. Corlette MB, Schatzky S, Ackroyd F (1978) Operative cholangiography and overlooked stones. Arch Surg 113: 729–734
11. Courvoisier LG (1980) Kasuistisch-statistische Beiträge zur Pathologie und Chirurgie der Gallenwege. Vogel, Leipzig
12. Feliciano DV, Mattox KL, Jordan GL (1980) The value of choledochoscopy in exploration of the CBD. Ann Surg 191: 649–654
13. Kehr H (1913) Die Praxis der Gallenwegschirurgie. Lehmanns, München
14. King ML, String TS (1983) Extent of choledochoscopic utilization in common bile duct explorations. Am J Surg 146: 322–324
15. Lennert K (1980) Choledochoskopie. Springer, Berlin Heidelberg New York
16. Shore JM, Morgenstern L, Berci G (1971) An improved rigid choledochoscopy. Am J Surg 122: 567–568
17. Shulman AG, Berci G (1985) Intraoperative biliary endoscopy (choledochoscopy) in California hospitals. Am J Surg 149: 703–704
18. Wildegans H (1953) Grenzen der Cholangiography und Aussichten der Endoskopie der tiefen Gallenwege. Med Klin 48: 1270–1272
19. Yamakawa T (1976) An improved choledocho-fiberscope and nonsurgical removal of retained biliary calculi under direct visual control. Gastrointest Endosc 22: 160–165