# Advanced Colonoscopy

## Principles and Techniques Beyond Simple Polypectomy

Toyooki Sonoda
*Editor*

VIDEOS
springerimages.com

Springer

# Advanced Colonoscopy

Toyooki Sonoda
Editor

# Advanced Colonoscopy

## Principles and Techniques Beyond Simple Polypectomy

Springer

*Editor*
Toyooki Sonoda, M.D., F.A.C.S., F.A.S.C.R.S.
New York Presbyterian Hospital
Weill Medical College of Cornell University
New York, NY, USA

Videos to this book can be accessed at http://www.springerimages.com/videos/978-1-4939-1583-5

ISBN 978-1-4939-1583-5 ISBN 978-1-4939-1584-2 (eBook)
DOI 10.1007/978-1-4939-1584-2
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2014948332

© Springer Science+Business Media New York 2014
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

*This textbook is dedicated to my wife and children, who give meaning to life every day.*

# Preface

The 1960s was the decade of development of fiberoptic technology to visualize the lumen of the colon. The flexible colonoscope revolutionized the evaluation and treatment of many diseases of the colon and rectum. Over the past two decades, the synergy between technology and gastrointestinal procedures has continued to deepen. Laparoscopy has become the standard of care in the treatment of many gastrointestinal disorders. Advances in endoscopy have allowed conditions that were in previous years designated for invasive surgery to be treated in a much less invasive way, within the lumen of the bowel. The eyes of the endoscopist have been enhanced by high-definition (HD) endoscopes, and the more recent evolution of magnified endoscopy has improved diagnostic accuracy. The hands of the endoscopist have been enhanced by improvements in snare design, various knives and forceps, intestinal stents, and luminal closure and suturing devices. These improvements in technology will certainly continue into the future, leading to the proliferation of truly complex endoluminal procedures.

For the practicing endoscopist, it is often difficult to stay current with the rapid advancement of technology. Formal training programs have thus been developed to teach the specialized skills of interventional gastroenterology. In Japan, therapeutic endoscopy has progressed more rapidly than in Western countries in regard to endoscopic removal of dysplastic and early malignant colonic lesions, mainly by the development of endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD). ESD in particular requires a specialized skill set and has quite the steep learning curve. As a result, many endoscopists, both Eastern and Western, hesitate to tackle the challenges of ESD while still possessing at least the desire to learn these invasive endoscopic procedures.

This book is intended to be a technical guide for practicing endoscopists to gain up-to-date knowledge and understanding of important advanced colonoscopic

---

Internet Access to Video Clip: The owner of this text will be able to access these video clips through Springer with the following internet link: http://www. springerimages.com/videos/978-1-4939-1583-5.

procedures. Each chapter is elegantly written by true experts in the field, with authors giving technical advice based on their own extensive experience. Chapters are accompanied by video clips of procedures performed by the authors. The topics of EMR and ESD are specifically written by Japanese endoscopists with tremendous experience in the subjects. Advanced colonoscopy is no doubt difficult and risky, and the adoption of these skills requires dexterity, patience, and a willingness to take risks. However, one must proceed with humility and common sense, always with the best interest of the patient in mind.

New York, NY, USA Toyooki Sonoda, M.D., F.A.C.S., F.A.S.C.R.S.

# Contents

# Contributors

**James M. Church, M.B.Ch.B., M.Med.Sci., F.R.A.C.S.** Department of Colorectal Surgery, Cleveland Clinic Foundation, Cleveland, OH, USA

**Ersilia M. DeFilippis, B.A.** Department of Gastroenterology and Hepatology, Weill Cornell Medical Center, New York Presbyterian Hospital, New York, NY, USA

**Mitsuhiro Fujishiro, M.D., Ph.D.** Department of Endoscopy and Endoscopic Surgery, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

Department of Gastroenterology, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

**Kelly A. Garrett, M.D., F.A.C.S., F.A.S.C.R.S.** Division of Colon and Rectal Surgery, Department of Surgery, Weill Cornell Medical College, New York Presbyterian Hospital, New York, NY, USA

**I. Emre Gorgun, M.D., F.A.C.S., F.A.S.C.R.S.** Department of Colorectal Surgery, Digestive Disease Institute, Cleveland Clinic, Cleveland, OH, USA

**Michel Kahaleh, M.D.** Department of Gastroenterology, Weill Cornell Medical College, New York, NY, USA

**Motohiko Kato, M.D., Ph.D.** Department of Gastroenterology, Tokyo Medical Centre, National Hospital Organization, Tokyo, Japan

**Kazuhiko Koike, M.D., Ph.D.** Department of Gastroenterology, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

**Nikhil A. Kumta, M.D.** Department of Gastroenterology and Hepatology, Weill Cornell Medical Center, New York Presbyterian Hospital, New York, NY, USA

**Sang W. Lee, M.D.** Department of Surgery, Weill Cornell Medical College, New York Presbyterian Hospital, New York, NY, USA

**Keiko Niimi, M.D., Ph.D.** Department of Endoscopy and Endoscopic Surgery, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

Department of Gastroenterology, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

**Reem Z. Sharaiha, M.D., M.S.** Department of Gastroenterology and Hepatology, Weill Cornell Medical College, New York Presbyterian Hospital, New York, NY, USA

**Ioana Smith, M.D.** Internal Medicine Program, University of Alabama in Birmingham, Birmingham, AL, USA

**Toyooki Sonoda, M.D., F.A.C.S., F.A.S.C.R.S.** Weill Cornell Medical College, New York Presbyterian Hospital, New York, NY, USA

**Brian G. Turner, M.D.** Department of Gastroenterology, Weill Cornell Medical College, New York, NY, USA

# Chapter 1
# Endoscopic Instruments

**I. Emre Gorgun**

**Abstract** Advanced colonoscopy by definition is not routine. It requires highly technical skills as well as advanced technology. When an endoscopist is equipped with the correct tools for the job, the chance of success improves. In this chapter, I will discuss the tools available and necessary to accomplish advanced endoscopy. First, we will touch on recent advances in colonoscopic design, different types of available snares, instruments necessary for endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD), i.e., needle knives and forceps, and how to improve visualization with special emphasis on chromoendoscopy.

**Keywords** Colonoscope • Snare types • Endoknife • Dual knife • Hook knife • $CO_2$ insufflation • Chromoendoscopy • Narrow-band imaging (NBI)

## Introduction

Colonoscopy is the gold standard for imaging in the colon and rectum [1]. It is widely used for screening, cancer and polyp surveillance, as well as for evaluation of symptomatic patients [2, 3]. The development of colon cancer screening programs in many countries has led to increasing numbers of patients undergoing optical colonoscopy. However, the procedure is invasive and can be associated with a wide spectrum of complications including perforation, splenic injury, post-polypectomy syndrome, mesenteric hemorrhage, diverticulitis, appendicitis, and even pancreatitis. Furthermore, colonoscopy may provide relatively poor protection against cancer in the right side of the colon [4]. Thus, improving visualization and the rate of adenoma detection are critical challenges for the future.

Another challenge is the removal of a difficult or large polyp. Currently, with few exceptions, benign but large sessile colonic polyps are referred to surgeons for segmental colorectal resection. These large colonic lesions could potentially

I.E. Gorgun, M.D., F.A.C.S., F.A.S.C.R.S. (✉)
Department of Colorectal Surgery, Digestive Disease Institute, Cleveland Clinic, Cleveland, OH, USA
e-mail: gorgune@ccf.org

© Springer Science+Business Media New York 2014

T. Sonoda (ed.), *Advanced Colonoscopy: Principles and Techniques Beyond Simple Polypectomy*, DOI 10.1007/978-1-4939-1584-2_1

be removed endoluminally but require advanced endoscopic techniques. These advanced techniques include endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD). One advantage to ESD is that polyps and large intraluminal lesions are removed in an "en bloc" fashion which allows for more precise histologic evaluation. Though technically difficult, the use of these approaches will in all likelihood expand, and endoluminal procedures will be more commonly performed for large intraluminal lesions in the future.

Improvements in endoscopic technique go hand in hand with improvements in endoscopic technology. Thus, to be successful in gastrointestinal endoscopy, knowledge of the currently available tools and endoscopes is essential. The current chapter will review different types of endoscopic equipment necessary for advanced colonoscopy, with suggestions about the best application of these tools. We will discuss different types of colonoscopes, snares, needle knives and forceps, $CO_2$ insufflation devices, and finally methods of chromoendoscopy.

## Colonoscopic Design and Modern Improvements

The traditional flexible endoscope (Fig. 1.1) is equipped with one "instrument" or "biopsy/suction" channel extending from the entry site of the biopsy port (Fig. 1.2) to the tip of the instrument. The channel is usually about 3 mm in diameter but varies from 1 to 5 mm depending upon the purpose for which the endoscope was designed (neonatal/ileoscopy to adult/large intestine). Separate air and water insufflation channels permit distension of the bowel and cleaning of the lens. During colonoscopy, the biopsy/suction channel is generally operated at the 6 o'clock orientation (Fig. 1.3). This practice allows fluid that is pooled by gravity to be suctioned easily and also allows easier manipulation of the forceps and snares. The length of most flexible endoscopes is between 100 and 160 cm.

**Fig. 1.1** Endoscope system (colonoscope)


**Fig. 1.2** Biopsy port

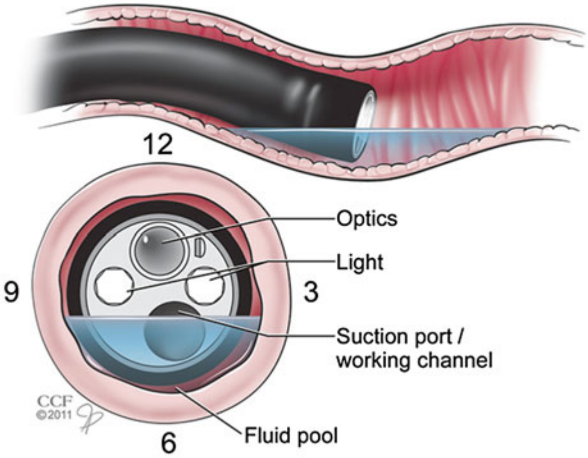



**Fig. 1.3** Manipulation of the "biopsy port" to the 6 o'clock position (Reprinted with permission, Cleveland Clinic, Center for Medical Art & Photography © 2011–2014. All Rights Reserved)

The need for further improvement in endoscopic techniques led to the development of a two-channel video colonoscope in 1993 [5]. Since this design has two instrument channels, both a grasping forceps and a snare can be inserted into the bowel lumen at the same time (Fig. 1.4). This enables lesions to be pulled into the center of the lumen and creates traction for electrocoagulation by the snare. The two-channel configuration maximizes versatility by permitting two instruments to be used simultaneously. Suction function can also be used from one or both channels concurrently. In dual-channel scopes, the two-channel construction incorporates one larger (3.2–3.8 mm) and one smaller (2.8 mm) diameter channels. One early study in 1996 demonstrated the use of a two-channel video colonoscope in the treatment of small carcinoid tumors of the rectum [6]. They reported that the complete resection rate for rectal carcinoids was significantly higher with a two-channel video colonoscope (90 %) than with a conventional one-channel scope (29 %), with neither bleeding nor perforation during


**Fig. 1.4** Dual channel scope, with two side-to-side instrument channels

or after treatment. However, many endoscopists believe that the operation of two instruments through the flexible endoscope is extremely challenging, especially when the instruments are intended to move in opposing directions. Therefore, endoscope manufacturers are currently working to develop articulating arms at the end of the flexible colonoscope which would function independently from each other and from the motions of the scope itself.

Success in colonoscopy depends on the ability to meticulously examine the mucosa behind folds and corners. Technologies have been developed to improve the ability to expose the mucosa on the proximal side of a colonic fold and beyond the corners. Among these advances are the wide-angle colonoscopy and the Third Eye® Retroscope® (Avantis Medical, Sunnyvale, California, USA). A wide-angle colonoscope produces a much wider field of visualization (170°) and has produced operator-dependent improvements in efficiency with faster withdrawal time. However, one randomized prospective trial did not report an overall improvement in rate of adenoma detection [7]. With the Third Eye® Retroscope® , a camera is passed down the instrument channel and provides a continuous retroflexed view on a second monitor. The endoscopist watches both the forward view from the colonoscope and the retrograde view simultaneously on side-by-side monitors. In a recent multicenter randomized controlled study investigating this technology, the polyp miss rate was lower when colonoscopy was first performed with the Third Eye® Retroscope® (18.4 %) compared with standard colonoscopy (31.4 %) [8, 9]. However, withdrawal time was significantly longer with the Third Eye® Retroscope® . This is likely in part because of the time required to remove and reintroduce supplementary instruments when a polyp is discovered, and also from the challenge of watching two screens simultaneously. Currently, single-port high-definition videoscopes are the most commonly utilized colonoscopes around the world (Fig. 1.1).

## Types of Snares

A polypectomy snare consists of a thin wire loop attached by a long connector that is enclosed within a 7-French plastic sheath. The plastic sheath holding the snare is passed through the "biopsy/suction" channel of the scope. The wire loop is opened and closed using the control handle (Fig. 1.5). This is controlled either by the endoscopy assistant or by the endoscopist. Some endoscopists prefer to hold the snare handle at the time of the polypectomy to feel tissue resistance and to control the speed of tissue transection. The snare handle connects to a generator via an electrosurgical cautery cord. Most snares are monopolar and require a grounding pad to complete the electrical circuit.

There are different types of polypectomy snares in regard to loop diameter, shape, design, and filament diameter. The wire loop is typically produced from braided stainless steel wire, which combines strength, memory of shape, and electrical conductance. More rigid monofilament snares allow faster transection over coagulation. The shape of the wire loop is usually *oval*, *elliptical*, *and hexagonal* (Fig. 1.6). Single-use snares are designed for easy insertion into the scope channel and provide more tactile feel and may reduce the risk of cutting too quickly. The soft snares feature a softer, more pliable wire so less force may be needed to open and close the loop. Rigid spiral snares are uniquely designed to minimize mucosal slippage when removing a flat lesion. The oval snares feature a thicker diameter wire designed to deliver a slower and more controlled cut. There are three commonly used oval snare sizes: small (1.5 × 3 cm), standard (2.5 × 5 cm), and "jumbo" (3 × 6 cm).

A needle tip snare provides secure anchoring of the snare tip to the mucosa, which prevents slippage of the snare at the initiation of snare closure. The Exacto® cold snare (US Endoscopy, Mentor, Ohio, USA) is a small (9 mm) snare that is used without electrocautery in circumstances of precise polyp excision (Fig. 1.6). The smaller diameter and shape of the snare allow for increased control of snare placement and resection. The Lariat® Lasso snare is a new polypectomy tool where three different sizes and shapes are available within the same instrument (Fig. 1.6). The configuration memory is a feature of the wire that allows the snare to be changed from oval (30 mm) to hexagonal (15 mm) to rhomboid (5 mm). The author's own experience with this new multi-shaped snare has been extremely satisfactory.

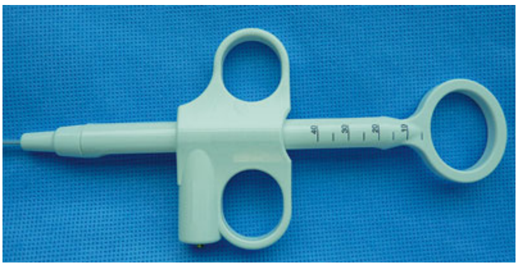


**Fig. 1.5** The control handle used to open and close a snare

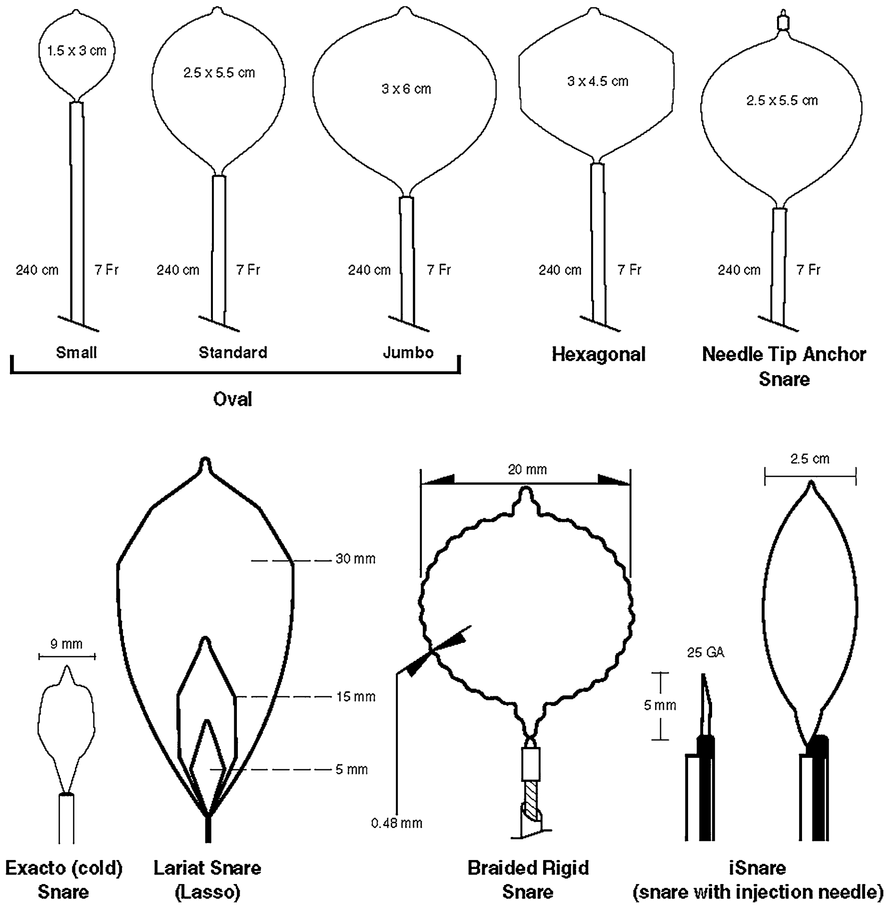



**Fig. 1.6** Different shapes and sizes of snares

Braided rigid snares deliver minimal slippage on the mucosa and are very beneficial for flat lesions (Fig. 1.6). Lastly, the iSnare® (US Endoscopy, Mentor Ohio, USA) is a snare that comes with a 25 G injection needle within the same sheath (Fig. 1.6). This adds efficiency during polypectomy procedures by eliminating device exchanges between needle injections and snare excision.

It is important to stock small, standard, and large-loop snares and maintain an appropriate inventory of "nonslip" snares, so that the correct snare is always available when needed. Additionally, one must not underestimate the importance of educating endoscopic assistants about the different types and specifications of snares; this will increase the chance of success during advanced endoscopic procedures.

## Tools Used in Endoscopic Mucosal Resection and Endoscopic Submucosal Dissection

One technique of endoscopic mucosal resection (EMR) involves the use of a variceal banding technology where a lesion is suctioned into a distal banding cap, and a flat lesion is turned into a pedunculated lesion. The narrow neck is then snared, and the lesion is removed easily. However, endoscopic submucosal dissection (ESD) involves a more advanced technique where submucosal injection and elevation of tissue planes are first achieved, followed by submucosal dissection using various types of needle knives. The advantage of ESD is that it allows an en bloc resection of an intestinal lesion, regardless of the size. This technique was first popularized in Japan for the treatment of early esophageal and gastric cancers [10]. The ESD method is widely used in the field of the upper gastrointestinal tract, especially in the stomach, because an en bloc resection not only offers postoperative organ preservation but exact histopathological diagnoses as well. In Japan, ESD is even performed for the treatment of early gastric carcinoma and superficial esophageal carcinoma.

The use of ESD for colorectal lesions has not yet been established as a standard therapeutic method; however, the use of ESD for colorectal lesions has been successful and studies are ongoing. Many types of endoscopic knives have been introduced and are available for use in colorectal ESD. Currently in the USA, there is no extensive experience with ESD. Our institution recently presented our early experience with ESD at the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) annual meeting in 2013 [11]. Since this presentation, we have increased our experience in colonic ESD. A total of 25 patients were referred to us for oncologic colorectal resection for large colorectal lesions. All studied patients were offered initial ESD in the operating room with possible bowel resection if ESD could not be successfully completed. A pediatric colonoscope (Olympus America Inc, Center Valley, PA) was used, and a transparent distal disposable cap was attached to the tip of the endoscope (Fig. 1.7). The lesion was first critically visualized either by dye injection, narrow-band imaging, or direct view. After this step, circumferential marking of the lesion with electrocoagulation was performed (Fig. 1.8). This was followed by submucosal injection using a mixture of saline, 2.5 % Hypromellose (HUB Pharmaceuticals, LLC, Rancho Cucamonga, CA) (Fig. 1.9) and indigo carmine solution (Fig. 1.10). This raises the submucosal plane and allows the procedure to be performed safely. The next step was mucosal incision with the dual knife, followed by submucosal dissection. The submucosal dissection was carried out by the alternating use of the DualKnife™, HookKnife™, and Coagrasper ™ (Olympus America Inc., Center Valley, PA) (Figs. 1.11, 1.12, and 1.13). The disposable distal cap facilitated the dissection in the correct submucosal plane. Once the entire lesion was dissected free, en bloc tissue retrieval was achieved and finally hemostasis was completed. In our series, the median age of the patients was 63 (range 50–88), median ASA score was 4 (2–5), and median body mass index (BMI) was 31 kg/m$^2$ (18–46). Lesions were located in the cecum (40 %), splenic flexure (20 %), sigmoid colon (20 %), transverse colon (10 %), and rectum (10 %). ESD was possible in 20

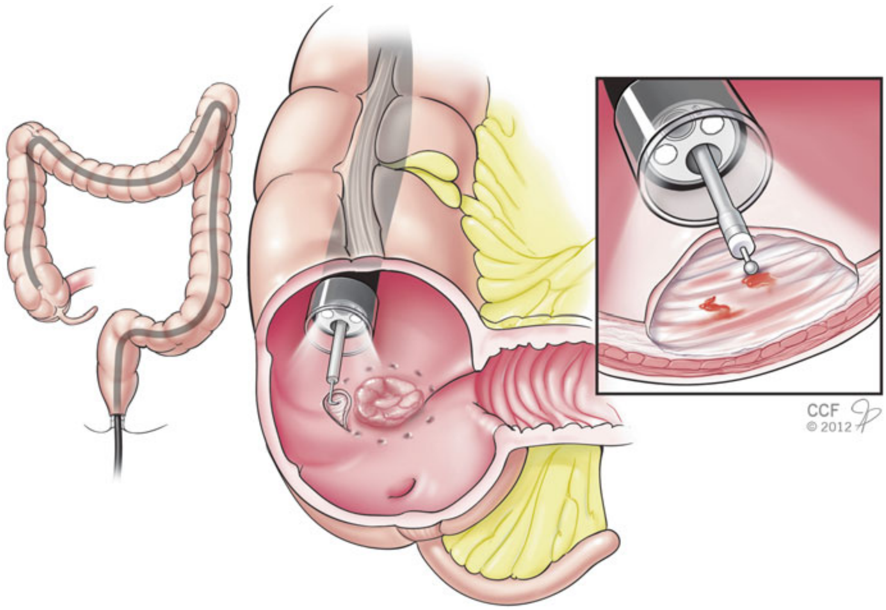



**Fig. 1.7** Endoscopic submucosal dissection (ESD) in the colon with a transparent tip cap (Reprinted with permission, Cleveland Clinic, Center for Medical Art & Photography © 2011–2014. All Rights Reserved)

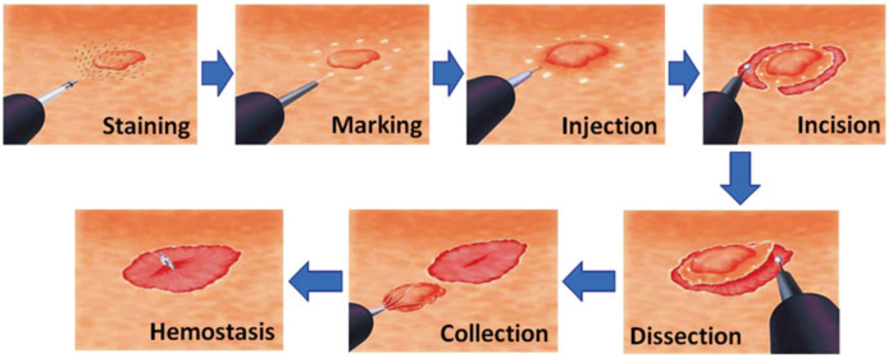



**Fig. 1.8** Sequential steps of endoscopic submucosal dissection (ESD) (Courtesy of Olympus)

of 25 lesions (80 %). Median operating time was 114 min (62–196). In five patients, ESD could not be technically performed due to non-lifting of the lesion, and either laparoscopic resection or endoscopic full thickness excision with laparoscopic repair of the defect was performed. There was no perforation or bleeding after ESD. The median length of hospital stay was 1 day (0–5). Follow-up colonoscopy was performed at 3 months, and no recurrence was encountered.

The following items are useful in ESD. Our personal experience has been to use each of the following tools for different particular steps and maneuvers.

**Fig. 1.9** Hypromellose solution. A hyperosmolar injection solution keeps the polyp lifted much longer than saline


**Fig. 1.10** Mixing indigo carmine blue dye to the injection solution improves visualization of the polyp edge and the submucosal plane

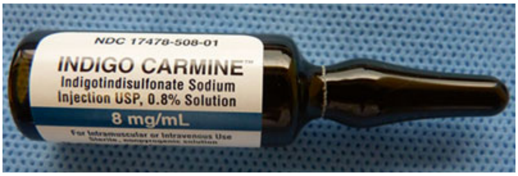
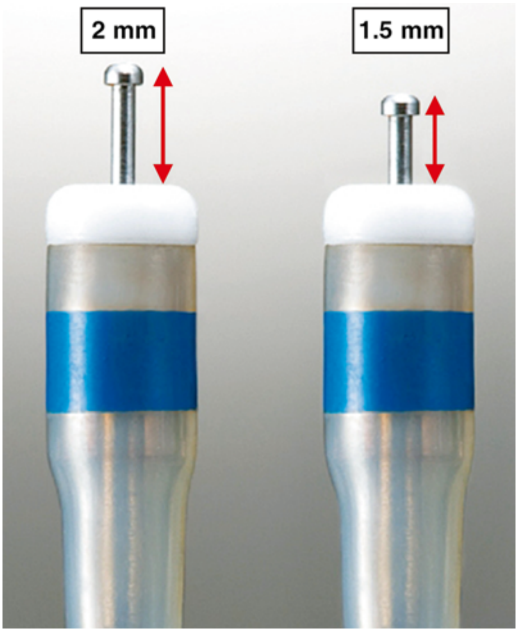



**Fig. 1.11** Dual knife. Useful for marking and dissection in ESD (Courtesy of Olympus)



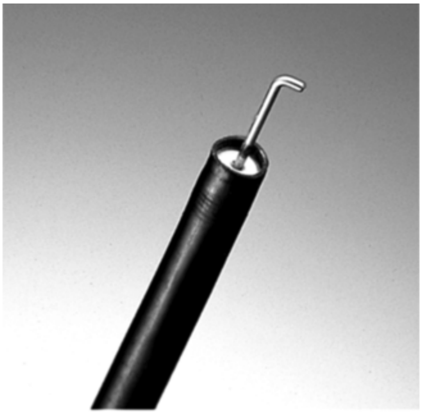


**Fig. 1.12** Hook knife. Controls depth of penetration as tissues are pulled away while energy is applied (Courtesy of Olympus)

**Fig. 1.13** Coagrasper. Helpful for larger submucosal vessels (Courtesy of Olympus)

## *Dual Knife*

The single-use Olympus DualKnife™ (Olympus America Inc., Center Valley, PA) electrosurgical knife features an adjustable two-step knife length and a dome-shaped cutting section designed to simplify marking and enable incision and dissection in all directions (Fig. 1.11). Distinct blue markers are visible on the sheath to provide endoscopic verification of cutting depth. The channel diameter is 2.8 mm, and working length is 165 cm for the upper gastrointestinal and 230 cm for the lower gastrointestinal system. Cutting knife length is 2.0 mm for upper gastrointestinal purposes and 1.5 mm for colonic applications. The purpose of the difference in cutting lengths is to prevent accidental bowel perforation due to wall thickness variance between the stomach and colon. When the handle is closed and the tip is pulled

**Fig. 1.14** The length of the knife in the Dual knife is controlled by the handle function (Courtesy of Olympus)

into the sheath, this facilitates the functions of marking and hemostasis. When the handle is open and the knife is deployed, this facilitates incision and dissection (Fig. 1.14).

## *Hook Knife*

The HookKnife™ (Olympus America Inc, Center Valley, PA) is a distal L-shaped hook with rotational function that allows for precise incision and dissection in longitudinal and lateral directions (Fig. 1.12). This type of tool is used to hook the tissue and draw it away from the mucosa while diathermy is applied, thus minimizing the risk of perforation. The turn and lock feature is simple to deploy and ensures the cutting wire is locked at the desired position during the procedure. A choice of lengths allows the endoscopist to choose a working length based on procedural technique or lesion location.

## *Coagrasper*

Coagrasper™ (Olympus America Inc., Center Valley, PA) provides precise and effective hemostasis by grasping a bleeding point or a visible vessel and coagulating it (Fig. 1.13). Excellent rotation function increases the accuracy of the grasper. Two types of cup shape and opening width are available for use in both the upper and lower gastrointestinal tracts. The single-use Coagrasper™ hemostatic forceps delivers targeted monopolar coagulation that creates hemostasis at the precise site of bleeding. A combination of mechanical and energy-based hemostasis device, the Coagrasper will isolate the vessel from the healthy surrounding mucosa so that thermal coagulation occurs only where needed.

### *Distal Disposable Cap*

Distal disposable cap is a transparent tip hood (Fig. 1.7) that is critical for tissue manipulation in colorectal ESD. A disposable distal attachment (Olympus America Inc, Center Valley, PA) is placed onto the tip of the colonoscope and aids in entry into the submucosa and lifts up the mucosa as to provide traction and countertraction during dissection. Additionally, the distal disposable cap adds stability during incision and improves the visual field by holding down the mucosa when needed.

### *Submucosal Injection Solution*

Hypromellose injection solution and indigo carmine blue dye play a central role in ESD (Figs. 1.9 and 1.10). The hyperosmolar injection solutions facilitate adequate submucosal elevation and safe dissection. The hyperosmolar feature allows the solution to remain in the submucosal plane for a long time compared to saline without dissipating too quickly. This is essential during a lengthy polypectomy. Although variable in practice, my preference is to dilute Hypromellose six- to eightfold using saline and mix small amounts of indigo carmine blue dye. The blue coloration of the submucosal plane provides better visualization of the structures and vasculature.

## $CO_2$ Insufflation

Gas insufflation is necessary to obtain optimal visualization of the intestinal surface during colonoscopy. However, insufflated air during colonoscopy remains in the bowel for a long time and results in prolonged bowel distension, abdominal pain, and discomfort. During and toward the end of a colonoscopy, the insufflated air cannot be completely suctioned, and the remaining air is not easily absorbed by the intestinal mucosa. On the other hand, the transluminal absorption of carbon dioxide ($CO_2$) is much faster (40–100 times) compared to air, improving patient comfort. This advantage is further magnified in the operating room, where intraluminal $CO_2$ insufflation has been noted to be advantageous when simultaneously combined with $CO_2$ laparoscopy by limiting bowel distension [12]. The feasibility of $CO_2$ insufflation during colonoscopy was first evaluated by Rogers [13]. The $CO_2$ Regulation Unit (Fig. 1.15) is simple to operate and can be run with no additional technical support. Most $CO_2$ units feature a single button on the front panel to start and stop the flow of $CO_2$. It is easily set up by connecting to a gas cylinder with a dedicated cylinder hose or by connecting directly to the hospital's medical gas supply. The units are usually small and compact and can fit easily into a standard endoscopy workstation. My recommendation is to use $CO_2$ insufflation for any lengthy polypectomy procedure.


**Fig. 1.15** The $CO_2$ insufflator

When intraoperative colonoscopy is needed as an adjunct to colorectal surgery, a downside of using air insufflation is prolonged bowel distension and obstructed surgical exposure. To test the safety of simultaneous $CO_2$ colonoscopy and laparoscopy, we conducted a case-matched study where the outcomes of patients undergoing laparoscopic intestinal resection with and without intraoperative colonoscopy were compared. The postoperative recovery and rate of complications were similar, and there were no complications related to $CO_2$ colonoscopy.

Laparoendoscopy is another emerging technique in which intraoperative colonoscopy plays a key role [14]. Laparoendoscopic polyp resection has been suggested as an alternative to segmental bowel resection for complete removal of large polyps [15]. With this technique, laparoscopic instruments are used to manipulate and stabilize the polyp-bearing segment of bowel from the serosal aspect, improving exposure for the endoscopist and increasing the chance of a successful endoscopic polypectomy [16]. Intraoperative $CO_2$ colonoscopy is extremely helpful in these combined procedures by limiting the amount of bowel distension and rendering clamping of the terminal ileum unnecessary.

## Chromoendoscopy and Narrow-Band Imaging (NBI)

The majority of endoscopes are videoscopes where light is transmitted to the tip of the instrument and reflected onto a charge-coupled device (CCD) chip. The CCD contains thousands of light-sensitive points or pixels that relay the image onto a video monitor. Image resolution is directly related to the number of pixels. Standard resolution endoscopes produce an image of 480–576 scanning lines on a screen.

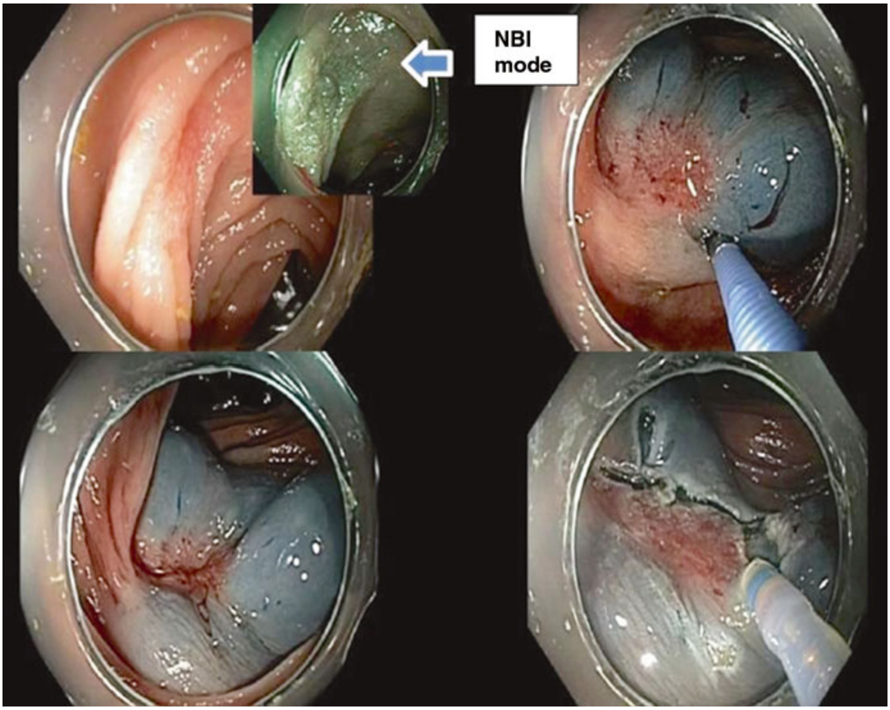



**Fig. 1.16** Narrow-band imaging (NBI) of a subtle lesion in a patient with inflammatory bowel disease removed by ESD. Both the NBI and the blue dye improve visual contrast of the lesion

High-definition (HD) CCDs can generate up to 1,080 scanning lines on a screen and has significantly improved image quality during colonoscopy. Despite this, it is still common that polyps are either difficult to visualize or missed entirely.

Chromoendoscopy is a technique that improves visual definition and characterization of mucosal lesions by the topical application of dyes. In simple terms, chromocolonoscopy is the process of endoscopically examining the colonic mucosa after it has been stained with dye. The goal is to allow the endoscopist to identify subtle features in abnormal mucosa, such as morphologically flat polyps or crypt patterns. Although absorptive stains, contrast stains, and reactive stains exist, the most common contrast dye used to spray mucosal lesions is indigo carmine solution, in concentrations between 0.1 and 0.8 %.

Recently, some advanced endoscopes have incorporated a new feature called narrow-band imaging (NBI). This digital technology allows for improved visualization and interpretation of mucosal changes without dye staining. NBI is an optical filter technology that optimizes the absorbance and scattering characteristics of light and radically improves the visibility of capillaries. It uses two discrete bands of light: one blue band at 415 nm and one green band at 540 nm. Narrow-band blue light displays superficial capillary networks, while green light displays subepithelial vessels, and when these two are combined, they offer an extremely high-contrast image of the tissue surface and submucosa. One of the advantages of such a system lies in the prompt availability of NBI by the push of a button on the endoscope. Hemoglobin absorbs a greater portion of the projected light thereby appearing darker on the image. This technology is available on most modern endoscopes and provides real-time information during colonoscopy. Studies examining the efficacy of chromocolonoscopy have shown that chromocolonoscopy increases polyp yield; however, most additional lesions are only small in size. Staining can also help in distinguishing neoplastic from benign polyps. One important use of this aspect of chromocolonoscopy is in inflammatory bowel disease (IBD), where its use may improve the detection of dysplasia [17]. Since chromoendoscopy increases procedure time, it may not be recommended for routine screening and surveillance, but its increased yield of dysplasia in IBD makes it a useful adjunct for surveillance in this population [18] (Fig. 1.16).

## Conclusion

To have a successful outcome in advanced colonoscopy, it is critical to be equipped with the appropriate tools. Thus, some of the current and most modern advancements useful for resection of difficult polyps were reviewed in this chapter. It is imperative that any endoscopist attempting to improve his/her skills be versatile and be familiar with a variety of equipment that will make the task at hand easier. As endoluminal procedures become even more and more complex, new innovations in technology will certainly be necessary to drive any major progress.

## References

1. Winawer SJ, Zauber AG, Ho MN, et al. Prevention of colorectal cancer by colonoscopic polypectomy. The National Polyp Study Workgroup. N Engl J Med. 1993;329:1977–81.
2. Winawer SJ, Zauber AG, Fletcher RH, et al. Guidelines for colonoscopy surveillance after polypectomy: a consensus update by the US Multi-Society Task Force on Colorectal Cancer and the American Cancer Society. Gastroenterology. 2006;130:1872–85.
3. Imperiale TF, Glowinski EA, Lin-Cooper C, et al. Five-year risk of colorectal neoplasia after negative screening colonoscopy. N Engl J Med. 2008;359:1218–24.
4. Brenner H, Hoffmeister M, Arndt V, et al. Protection from right- and left-sided colorectal neoplasms after colonoscopy: population-based study. J Natl Cancer Inst. 2010;102:89–95.
5. Cho E, Ashihara T, Nakajima M, et al. Clinical evaluation of prototype 2-channels electronic videocolonoscope (CF-2T200I). Gastroenterol Endosc (Tokyo). 1993;35:289–94.
6. Iishi H, Tatsuta M, Yano H, et al. More effective endoscopic resection with a two-channel colonoscope for carcinoid tumors of the rectum. Dis Colon Rectum. 1996;39(12):1438–9.
7. Fatima H, Rex DK, Rothstein R, et al. Cecal insertion and withdrawal times with wide-angle versus standard colonoscopes: a randomized controlled trial. Clin Gastroenterol Hepatol. 2008;6:109–14.
8. Waye JD. Improving lesion detection during colonoscopy. Gastroenterol Hepatol (NY). 2010;6:647–52.

9. Leufkens AM, DeMarco DC, Rastogi A, et al. Effect of a retrograde-viewing device on adenoma detection rate during colonoscopy: the TERRACE study. Gastrointest Endosc. 2011;73:480–9.
10. Ono H, Kondo H, Gotoda T, Shirao K, Yamaguchi H, Saito D, et al. Endoscopic mucosal resection for treatment of early gastric cancer. Gut. 2001;48:225–9.
11. Gorgun E, Remzi F. Endoscopic submucosal dissection for large non pedunculated lesions of the colon: early experience in the United States. Baltimore, MD: SAGES; 2013.
12. Nakajima K, Lee SW, Sonoda T, Milsom JW. Intraoperative carbon dioxide colonoscopy: a safe insufflation alternative for locating colonic lesions during laparoscopic surgery. Surg Endosc. 2005;19:321–5.
13. Rogers BH. $CO_2$ during colonoscopy for safety and comfort. Gastrointest Endosc. 1985;31:108–9.
14. Park YA, Jung EJ, Han SJ. Laparoscopic resection of duplicated sigmoid colon under the guidance of intraoperative colonoscopy. Surg Laparosc Endosc Percutan Tech. 2005;15:299–301.
15. Wilhelm D, von Delius S, Weber L, Meining A, Schneider A, Friess H, Schmid RM, Frimberger E, Feussner H. Combined laparoscopic-endoscopic resections of colorectal polyps: 10-year experience and follow-up. Surg Endosc. 2009;23:688–93.
16. Smedh K, Skullman S, Kald A, Anderberg B, Nyström P. Laparoscopic bowel mobilization combined with intraoperative colonoscopic polypectomy in patients with an inaccessible polyp of the colon. Surg Endosc. 1997;11:643–4.
17. Kaltenbach T, Friedland S, Soetikno R. A randomised tandem colonoscopy trial of narrow band imaging versus white light examination to compare neoplasia miss rates. Gut. 2008;57:1406–12.
18. van den Broek FJC, Fockens P, van Eeden S, et al. Endoscopic tri-modal imaging for surveillance in ulcerative colitis: randomised comparison of high resolution endoscopy and autofluorescence imaging for neoplasia detection; and evaluation of narrowband imaging for classification of lesions. Gut. 2008;57:1083–9.