Enlan Xia
Editor

Practical Manual of Hysteroscopy

河南科学技术出版社
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ISBN 978-981-19-1331-0 ISBN 978-981-19-1332-7 (eBook)
https://doi.org/10.1007/978-981-19-1332-7

B&R Book Program
Jointly published with Henan Science and Technology Press

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Foreword to the Third Edition

It has been 6 years since the publication of the second edition of *Practical Manual of Hysteroscopy*. During this period, hysteroscopy has been widely practiced in clinics and has developed rapidly. Hysteroscopic diagnosis with localized biopsy is the golden standard for modern diagnosis of intrauterine pathologies. Hysteroscopic surgery has been widely accepted because of its low traumatic ratio, high potency ratio, excellent efficacy, and irreplaceability. It has been described as a model of successful modern minimal traumatic surgery and has been one of four main gynecological surgeries which are commonly used (hysteroscopy, laparoscopy, laparotomy, and transvaginal surgery). By retrieving hysteroscopic-related literatures published in these 6 years, 7925 papers were found from China National Knowledge Infrastructure (CNKI), and 1520 papers from MEDLINE, which showed active academic activities and wide applications in the field of hysteroscopy. By writing the third edition of *An Atlas of Hysteroscopy*, we undergo some supplement and revision according to the advancements of basic research and clinical application at home and abroad in recent years, combining with our own practical experience in our center. We hope that this book will be of great benefit to gynecologists in studying, grasping, advocating, and even teaching hysteroscopic technique.

In total, there are 16 chapters, more than 380,000 words, and 760 pictures included in this book. The revised item is Sect. 2.4, Chap. 2—Cleaning, Sterilization, and Maintenance of Hysteroscopic Instruments. It introduced the disinfection of hysteroscopic instruments in the second edition, including bacteriostasis and sterilization. In the third edition, the sterilization of hysteroscopic instruments is described, as bacteriostasis was obsoleted. The contents added include: (1) A new classification of uterine malformation: there is a new classification system of female genital malformations and jointly published by European Society of Human Reproduction and Embryology (ESHRE) and European Society for Gynecological Endoscopy (ESGE). This system is simple and memorable with high practicability and achieves the approval of most clinical gynecologists. (2) Metroplasty for a rare form of uterine malformation: it includes Robert uterus, complete bicornuate uterus, unicornuate uterus, and "T"-shaped uterus. Transcervical uterine incision (TCUI) excises the excessive myometrial tissues on uterine lateral walls or cuts the thickened myometrium on one or two lateral walls so as to improve the shape of the uterus, enlarge the uterine cavity, relieve intrauterine pressure, improve endometrial blood supply to facilitate the implantation of fertilized eggs, prevent miscarriage, and improve the reproductive outcomes. Combined hysteroscopic and laparoscopic metroplasty for complete bicornuate uterus is performed under laparoscopic monitoring, the hysteroscopic electrode is used to incise the intrauterine plate and the fundus to serosal layer, causing artificial perforation. Then transversely incise the full layer of the fundus and suture the incised wall longitudinally by laparoscopy to achieve a normal shape cavity and increase the possibility of fertility. Some infertile women who were treated in our center for these malformations have delivered healthy infants after metroplasty. (3) The advancement of diagnosing and treating adenomyosis: it includes the findings under hysteroscopy, which can make the diagnosis in early stage; hysteroscopic surgery for cystic adenomyosis can replace the removal of uterine corpus or partial uterus, and obtain the possibility of fertility; the joint application of phloroglucinol dehydrate, narrow band imaging (NBI) hysteroscopy, levonorgestrel-releasing intrauterine system (LNG-IUS), GnRH analog, and hysteroscopic endometrial resection for treatment of adenomyosis, which can enhance the effect of GnRH-a and TCRE and meet the patients' desire to preserve the uterus. (4) Transcervical resection of diffuse uterine leiomyomatosis (DUL): after operation, the endometrium can recover within 2 to 3 months, the improvement of menstruation achieved 93.5%, the recurrence rate was 32.3%, and some patients obtained conception and birth. (5) The prevention of adhesion recurrence after transcervical resection of intrauterine adhesions (TCRA): adjunctive therapies such as postoperative hormone treatment, intrauterine placement of balloon catheter, insertion of human amnion graft, instillation of auto-cross-linked HA (ACP) gel, application of prophylactic antibiotics, and second-look hysteroscopy have been discussed. (6) NBI hysteroscopy: NBI utilizes the light absorption properties of hemoglobin at a certain wavelength to improve the contrast of blood vessels in superficial endometrial layer and well display the mini-structure of the endometrium; therefore it could facilitate the identification of endometrial atypical lesions. It can be used in hysteroscopy so that it can discover the endometrial lesions in early stage, make localized biopsy, and increase the discovery rate of precancerous lesion and endometrial cancer. (7) Pretreatment of cervix with phloroglucinol: it is a pro-muscle non-atropine non-papaverine class pure smooth muscle antispasmodic agent, which is applied in hysteroscopic examination and operation, and has analgesic and cervical looseness effects. (8) Paradoxical emboli caused by venous air embolism with gas emboli entering the left heart: in 2008, Rademaker et al. first reported on one case of fatal paradoxical gas embolism with gas emboli entering the left heart from the right heart through atrial septal defect, open foramen ovale, pulmonary arterio-venous malformations, or arterio-venous fistula.

I would like to express my acknowledgment to all people who provided us with generous help during my compilation of this book, such as Li Jing and Zhong Qin from Scientific Research Office of Fuxing Hospital; Mr. Liu Xuegang and Mr. He Baijiang, who are former managers of Endoscope Marketing Department, Olympus (Beijing) Ltd.; and Mrs. Zhang Zhen from Endoscope Marketing Department, Olympus (Beijing) Ltd. I would also like to thank all colleagues, advanced training physicians, and graduate students in our department for their cooperation!

Any mistake and deficiency due to our limited experience will hopefully be pointed out and forgiven!

Beijing, China Enlan Xia
August 31, 2014

Foreword to the Second Edition

With the development of a holistic concept of surgical treatment in the 1970s, an aggregative indicator, including patients' physiological condition, social activities, and mental outlook, has become an important indicator for the assessment of surgical outcomes and a research object. The introduction of advanced technology prompts the minimally invasive concept and minimally invasive surgery to develop gradually and boom. As an important part of the minimally invasive surgery, the development of hysteroscopy has changed the diagnosis and treatment pattern of the traditional gynecological diseases, which can not only bring about the benefits of minimally invasive surgery, including less trauma, less intraoperative bleeding, few complications, low cost, short hospitalization, and quick recovery, but also preserve the uterus, improve the reproductive prognosis, and cope skillfully with such intractable conditions as vaginal foreign body, cervical/intrauterine lesions, asymmetric septate uterus, and oblique vaginal septum, which is hard to deal with even in an open surgery. Hysteroscopy can be used to diagnose almost all the intrauterine benign diseases like intrauterine lesions, dysfunctional uterine bleeding, submucous myoma, septal deformities, endometrial polyps, intrauterine adhesions, removal of foreign bodies, et al. and can replace, even be superior to traditional open surgery. So hysteroscopy has become a revolutionary event and a milestone in the developmental history of gynecology. Hysteroscopic technology is characterized by its minimal invasiveness, which offers doctors a golden platform to open up new fields of application, and thus making their professional career prolonged and more colorful.

Over the past 10 years, there has been a rapid development of hysteroscopic technology in our country, the gap with the international advanced level has been narrowed ceaselessly, and both the hysteroscopic philosophy and technique have been greatly improved. Encouraged by Henan Science and Technology Press, 5 years ago, we edited a book *An Atlas of Hysteroscopy* together with experts in hysteroscopy at home and abroad, and this book has been widely appreciated by readers.

Time slipped away little by little, and 5 more years passed away unnoticed. There have been a lot of new advances in hysteroscopic technology over time. Firstly, the improved instruments and devices—the integrated hysteroscope has integrated the double advantages of flexible and rigid hysteroscope, which can not only further relieve patients' pains and improve the therapeutic effects but also make doctors feel more intuitively the motive force of the progress in instruments on the development of therapeutic techniques and clinical treatment. Secondly, the application of transvaginal endoscope has turned hysteroscopic examination into a noninvasive procedure. Hysteroscopy has been widely used in the diagnosis and treatment of infertility, and a consensus has been reached that hysteroscopic surgical treatment for intrauterine abnormalities is superior in reproductive prognosis to traditional surgery. In 2006, plasma bipolar resectoscope came into being in China. The use of bipolar resectoscope with saline as irrigation fluid is unlikely to cause hyponatremia and safer than monopolar resectoscope. A second look following resection of severe intrauterine adhesions may prevent reformation of adhesion and multiple surgeries and can restore the normal morphology of uterine cavity, which has been widely accepted. And the postoperative pregnancy rate may reach 28.7%–53.6%. With the wide application of operative hysteroscopy and accumulation of experiences, it has become a safe and minimally invasive surgery with excellent prognosis and few complications and is easy to learn. There has been a change in the sequence of complication occurrence, the risk of false passage and uterine perforation rises to be the first. Gas embolism is the most dangerous complication and can be prevented if strict precautions are taken. Second-generation endometrial ablation procedure is simpler and quicker than first-generation monopolar electroresection, but similar in satisfaction rate and the effect of reducing blood loss. And complications occur after both first-generation and second-generation endometrial ablation. On the occasion of the reprinting of this book, the above advances in hysteroscopy will be expatiated in the related chapters for readers.

I dedicate this book to my first teacher in hysteroscopy Prof. Lin Yuanying and also to Prof. Song Hongzhao, Prof. Zhou Suwen, Prof. Li Zixin, and Prof. Liu Zongtang, who gave me a lot of support and encouragement. And my most sincere gratitude goes to Mr. Liu Xuegang, Mr. He Baijiang, Mrs. Li Jihong, Mrs. Liu Ya'an, and Mrs. Zhang Meng from Japan's Olympus Corp., who helped me in collecting images and providing equipment and technical support.

December 20, 2008 Enlan Xia

Foreword to the First Edition

The application of diagnostic hysteroscopy and operative hysteroscopy and other new techniques provides an economic, feasible, simple, and effective way in the clinical treatment of intrauterine benign lesions. At present, diagnostic hysteroscopy is the gold standard for diagnosing intrauterine lesions and is gradually replacing the blind diagnostic curettage. And operative hysteroscopy has become the optimal surgical procedure in treating dysfunctional uterine bleeding and also the standard surgical procedure for the treatment of uterine septum and the gold standard for treating endometrial polyps. A great deal of follow-up study has confirmed the efficacy of hysteroscopic electroresection in the treatment of benign intrauterine lesions. Operative hysteroscopy has the minimal ratio of internal trauma and the maximal ratio of cost and effect, so it is called a model of successful minimally invasive surgery. In our country, as the clinical application of hysteroscopic diagnosis and therapeutics has been popularized day by day, the hysteroscopic technique has been applied more extensively in recent years.

Tracing back to the developmental history of hysteroscopic techniques in China, we could not forget the late specialist in obstetrics and gynecology, Prof. Lin Yuanying, PhD. He was the first person to advocate the development of hysteroscopy in China, who had ever worked in the Department of Gynecology and Obstetrics of former Shanghai Municipal First People's Hospital. I had the honor to be admitted to this hospital for further education between 1964 and 1965 and was instructed by respectful Professor Lin. At that time, he was there to guide the joint development of hysteroscope with the medical instrument factory and to observe an isolated uterus. Professor Lin's careful thinking, rigorous style of work, and relentless pursuit impressed me deeply. Inspired by his spirit, I inherited my teacher's unfulfilled wish. Since 1990, I have committed myself to the introduction, clinical application, and basic research of hysteroscopy, and I have accumulated a large number of image data. Today, hysteroscopic technique has already been mature. To popularize this procedure in our country and benefit the broad masses of women, the Ministry of Health has listed hysteroscopic techniques as one of 10-year 100 projects of 2001. In view of fewer related works at present and lack of systematic atlas monographs, well-known experts and scholars domestic and abroad were invited to edit this book under the energetic support of Henan Science and Technology Press.

I dedicate this book to my first teacher in hysteroscopy Prof. Lin Yuanying and also to Prof. Song Hongzhao, Prof. Zhou Suwen, Prof. Li Zixin, and Prof. Liu Zongtang, who supported and encouraged me a lot. And my most sincere gratitude goes to Mr. Liu Xuegang, Mr. He Baijiang, Mrs. Li Jihong, Mrs. Liu Ya'an, and Mrs. Zhang Meng from Japan's Olympus Corp. Beijing Office, who helped me in collecting images and providing equipment and technical support.

I sincerely welcome colleagues domestic and abroad to give me more valuable advice so as to make it better in time if there are some careless omissions.

In April 2001, the tenth meeting of the International Society for Gynecologic Endoscopy held in Chicago, USA, put forward a target to the gynecological workers of the whole world: "To 2025, most of gynecological surgeries will be replaced by endoscopic operations." This will inspire and guide us to develop our hysteroscopic techniques and render unremitting efforts to the implementation of international standards.

June 2002 Enlan Xia

Preface

This is a delicate book with precious atlas and a fruit of hard work. As a monograph on medicine, we'd rather attach much importance to great amounts of data obtained through long time of practice, accumulation and summarization combined with scientific analyses and elaboration in relation to academic viewpoints. In view of clinical medicine involving highly practical technology, especially the laboratory techniques and operating techniques, their popularization is of great significance. And clear elaboration, lucid expression, and justified statement on the latter are extremely difficult to make.

However, after I read through the book *An Atlas of Hysteroscopy*, edited by Prof. Xia Enlan, I felt shocked and greatly excited! The reason is that this is just the kind of professional works on technology that we have expected. And its contributors are all experienced experts in hysteroscopy especially those from the hysteroscopic center under the leadership of Prof. Xia, who are richly experienced and have achieved brilliant achievements. And more valuably, this center has constantly recruited visiting physicians and postgraduates and has trained a large number of professional and technical personnel throughout the year, so this is a well-deserved training center and a cradle of specialists.

Hysteroscopy and laparoscopy, being a major tool and technical source of gynecological endoscopy, have been widely extended in their diagnosis and treatment and have promising prospects. If you'd like to make good use of them, first, you should know well about their indications and contraindications, then, have a good command of their techniques and skills, and you also should be always on guard against the occurrence of complications. Standardization of techniques and training for operators are indispensable "double-track railway" in the progress of technology. Endoscope-related accessories, energy source, and limited space and vision have posed new problems for surgery, so it seemingly becomes a "double-edged sword," that is, a minimally invasive surgery may be turned into a maximally invasive surgery. And through reading this book you may grasp its gist and understand its meanings. So when such kind of book is often called "cookbook," I beg to differ. And what's more, even though it is a cookbook, the ingredients and procedures described, if managed by different hands, may have quite different flavors! How important the cooking skill and cooking temperature control is! Let alone the much more complex hysteroscopic technique. Illness differs from person to person, so we can't "look for a steed with the aid of its picture"; it depends on individual's power of understanding, intelligence, experience, and personal skill. Learning from others through reading improves one's own ability, in a sense, as the saying implies, "Laymen are overwhelmed by the fun while professionals try to find out the trick" and "A master may teach, but progress is up to the hard work of an individual." We are running after a lot of new dreams (they are not necessarily all splendid), but more importantly, we need calmness and reflection, including summarization, analysis, and deduction from our daily work, just as the book contributed by Prof. Xia together with other authors.

Professor Xia is our respectable senior. Upon her order, I wrote these out of my own heart, which aren't be but a preface.

Beijing, China Jinghe Lang

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and Peking Union Medical College
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Obstetrics and Gynaecology in Peking Union
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At Mid-Autumn of 2002

Abstract

The book is made up of 16 chapters, in which a systemic introduction is made to the history of hysteroscopy, hysteroscopic equipment and instruments, applied anatomy and histology in relation to hysteroscopy, distention media and perfusion system, anesthesia for hysteroscopy, and so on. This book elaborates on the application of diagnostic hysteroscopy and operative hysteroscopy in the treatment of gynecological diseases, combined hysteroscopy and laparoscopy, and hysteroscopic surgery under ultrasound monitoring. This book also expounds incisively on the technical training and the trend in the future development of hysteroscopy. At the end of this book, a report sheet of hysteroscopic examination, routine orders in hysteroscopic ward, patient consent form prior to hysteroscopic surgery, and operating manual for hysteroscopic electroresection are attached so as to help readers to standardize the hysteroscopic examination, diagnosis, and surgeries.

This book is based on rigorous and scientific research with emphasis on a combination of theory and practice, in which various typical cases are redisplayed clearly by more than 700 color photos to facilitate readers' understanding and grasp of hysteroscopy. Meanwhile, it is also a professional and reference book for medical students, gynecologists, and nurses at all levels to use.

Cataloguing in publication (CIP) data

An Atlas of Hysteroscopy/Edited by Xia EnLan—the third edition

An Atlas of Hysteroscopy/Editor-in-chief: Xia EnLan.—third edition.—Zheng Zhou: Henan Science and Technology Press, 2015.4

ISBN 978-7-5349-3958-7

I. Hysteroscopy II. Xia EnLan III. Hysteroscopy—Atlas IV.R711.740.4–64

Chinese Version Library CIP Data Reg. No. 118839 (2008)

Published and issued by: Henan Science and Technology Press

Address: Jingwu Road No. 66, Zhengzhou City, China

Postcode: 450002

Tel: 0086-(0)371-65737028 65788627

URL: www.hnstp.cn

Editor in charge: Ma Yanru

Proofreader in charge: Ke Jiao

Cover designer: Zhang Wei

Layout designer: Sun Song

Printed by: Zhengzhou New Coast Computer Color Printing CO., Ltd

Distributed by: National Xinhua Book Stores

Page size: 185 mm × 260 mm

Printed sheet: 29.5 Number of words: 580,000

Edition: Third published in May 2015. First Printed in May 2015

Contents

5 Application of High Frequency Electricity in Hysteroscopic Surgery and Its Thermal Effects on Tissues

Hua Duan

In 1924, Wyeth first found that high power and high frequency (HF) damped waves were able to incise tissues, and then high frequency damped wave electrotome was developed and applied in surgery by Anderson et al. In 1928, Bovieh and Cushing developed a high frequency undamped wave electrotome, which laid the basic foundation of high frequency electricity in the surgical treatment. In recent years, high frequency electricity has been proved to be safe, efficient, easily handled, and manipulated, and has been widely used in hysteroscopic surgery and improved quickly.

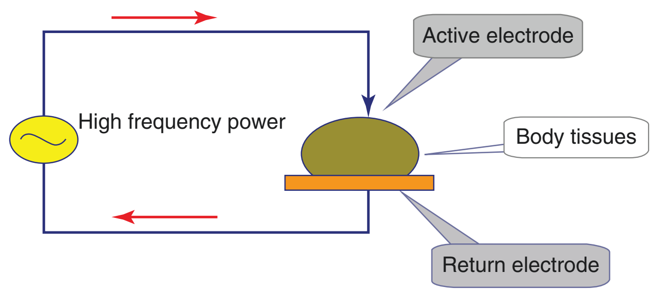

Fig. 5.1 Electrical circuit and its role

5.1 The Electronic Circuit Compositions and Current Types in Hysteroscopic Electrosurgery

5.1.1 The Electronic Circuit Compositions in Hysteroscopic Electrosurgery

High frequency electrosurgery refers to that the electric current of a certain intensity runs under the set voltage through the active electrode into the biological tissue to produce the electrothermal effects and cause expected damage to the target tissues, thus achieving the purpose of treatment. As shown in Fig. 5.1, in high frequency circuit system of hysteroscopic surgery, a part of the body tissue exposes to the median of two electrodes: one is an active electrode and the other is a return electrode (negative plate). In operation, high frequency current runs in the direction of the arrow along the tissues. Since there is only a narrow surface area between the active electrode and the body tissues, the current density is relatively high; but the return electrode has a larger contact area with the body tissues, so the current density is relatively low.

The changes of the temperature in human tissues are proportional to the square of current density. Therefore, when the high frequency current passes, the temperature of human tissues under the active electrode rises very quickly, while less heat is produced at the negative plate, which can be neglected. Thus, in a closed high frequency electrical circuit, the electric cutting, electrocoagulation, electrocautery, or other high frequency electrosurgery on body tissues are limited to the areas in contact with active electrode, so that high frequency electrosurgery could be done smoothly.

Electrocautery is different from electrosurgery. Electrocautery is to heat the metal conductor by electricity, and then acts on the tissues. Through the physical transfer of heat, the thermal destructive effect is achieved. Usually, the thermal effect temperature between the heated metal conductor and the biological tissues can reach 60 °C to 90 °C, therefore, it can only be used for coagulating tissues. However, electrosurgery is to have high frequency current of a certain intensity run under the set voltage through the active electrode into the biological tissue, achieving the electrothermal effect. The electrothermal temperature can be up to 100 °C–500 °C, thus the expected destruction and treatment can be implemented to the pathological tissues.

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E. Xia (ed.), *Practical Manual of Hysteroscopy*, https://doi.org/10.1007/978-981-19-1332-7_5

5.1.2 Current Types in Hysteroscopic Electrosurgery

The commonly used types of high frequency electrical current in hysteroscopic operation are mainly cutting current and coagulating current.

5.1.2.1 Cutting Current

The high frequency current that maintains a continuous output and produces cutting effects on biological tissues in electrosurgery is known as cutting current. The characteristics of its wave pattern are continuous undamped sine waves. As shown in the graph (Fig. 5.2), one may see that at a certain voltage, the current is oscillating at an extremely high frequency between the positive and negative electrodes. Due to the continuous current output, the cutting current has relatively higher average energy, and it also has no electric energy attenuation in the process of current output. When this continuous, undamped high frequency current acts on the biological tissues through the tiny active electrode (cutting electrode in hysteroscopic operation), it produces an extremely high current density on local tissues so as to heat up the local tissue rapidly, and causes vaporization and cell rupture, thus producing the cutting effect. During the cutting process, on the one hand, the intracellular heat is dispersed by the cell rupture resulting from high temperature, which prevents the heat transfer and infiltration from the site with high temperature to the adjacent tissues, producing "autonomous cooling effect." On the other hand, the high temperature carbonization of the tissue cells beneath the cutting surface increases tissue resistance and limits the conduction of electrothermal effects to the deeper tissues.

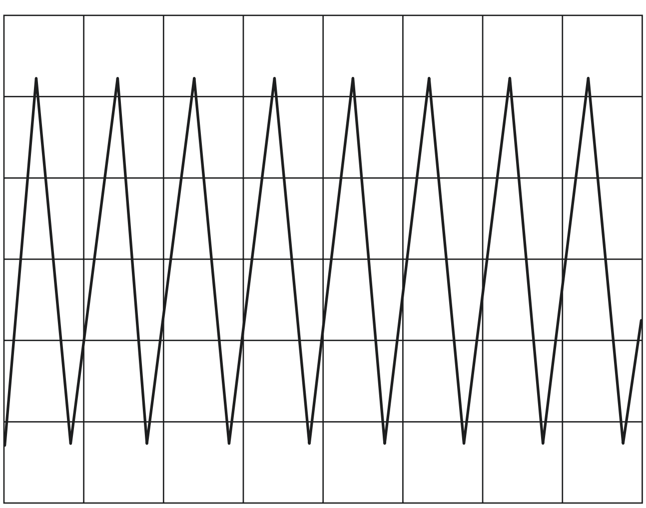

Fig. 5.2 Wave pattern of cutting current (continuous undamped waves)

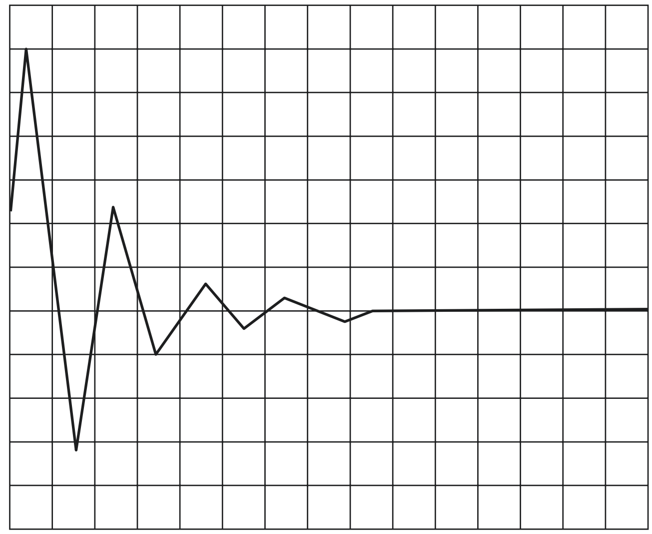

Fig. 5.3 Wave pattern of coagulating current (pulse damped wave)

5.1.2.2 Coagulating Current

Contrast to the cutting current, the high frequency current that changes the continuous output forms and produces coagulating effects on biological tissues is known as coagulating current. Its wave pattern characteristics are intermittent pulse damped waves (Fig. 5.3) and electric energy attenuation occurs in the process of current output. It is due to the electric energy attenuation of the coagulating current, the quantity of heat produced by tissues is reduced more significantly than the undamped current at the same voltage. In electrosurgery, the roles of coagulating current include desiccation and fulguration. When the coagulating current produces coagulating effect through the contact of rollerball electrode with tissues, because the contact area is larger than that of the cutting current, the current density passing through the contact surface is less than that of the cutting current. Therefore, at a higher voltage output, a wide range of tissue thermal damages may be resulted. Along with the increased distance away from the active electrode, the temperature conduction of its tissue thermal effect drops gradually. And when the temperature is over 45 °C, the thermal damage to tissue cells is closely related to the action time of the electrode.

5.1.2.3 Blended Current

Since the cutting current is different from the coagulating current in wave pattern characteristics, the electrothermal effect on tissues is also different. Therefore, cutting tissues combined with some coagulating current can often achieve a better clinical effect. This blended current usually manifests as blended damped and undamped waves (Fig. 5.4).

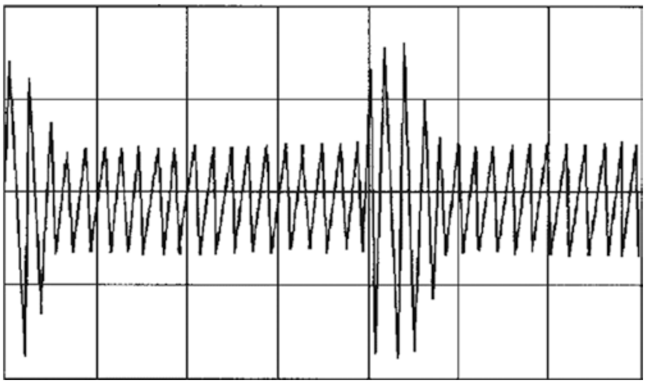

Fig. 5.4 Blended wave pattern of cutting and coagulating current

5.2 Electrothermal Effects in Hysteroscopic Surgery and Its Impact on the Tissues

5.2.1 The Changes in Tissue Cells Caused by Electrothermal Effects

5.2.1.1 Influence of Electrothermal Effect on Protein

Protein has high molecular weight and a complex composition and structure. The bond energy of secondary bonding (non-covalent) which maintains the molecular conformation is relatively low, thus its molecular structure is unstable and easily influenced by physical and chemical factors, leading to the destruction of its spatial conformation, change of its physicochemical properties, decrease of its stability and loss of the biological functions. All of them result in the denaturation of protein. High temperature can make the protein molecules denatured by rupturing the secondary bond. Generally, protein denaturation may occur at 60 °C. However, the usual active cells may die by producing protein denaturation when they are at the temperature of 600 °C for only 1 s.

5.2.1.2 Influence of Electrothermal Effect on Enzymes

Enzyme is one kind of protein with catalytic properties produced by active cells. In the metabolic process of the living organisms, almost every chemical reaction is induced by some enzymes. Enzyme is biological catalyst, so enzyme-induced reaction is similar to the general chemical reaction, that is, the temperature increases, the reaction speed is quickened. However, the enzyme is also a type of protein, and will denature at high temperatures. When the temperature reaches 60 °C, the enzymatic activity is obviously lower, and at 80 °C, the enzymatic activity is completely lost.

5.2.2 Influence of the Electrothermal Effect on Uterine Tissues

The thermal damage to the tissues during hysteroscopic surgery has been a focus of attention of gynecologic endoscopic surgeons. Due to the complexity of the factors related to the study, especially living tissue specimens are not easy to get, the further knowledge of this issue is restricted. The scholars who studied the isolated uterine specimens and some living uteruses drew the following conclusions: the depth of the endometrial damage is not related to the power of the electrode; there are variations in the depth of tissue thermal damage caused by different current waveforms; the tissue damages are related to the action time of the electrode. Indman et al. carried out studies of the electrothermal effects on the uterus in vivo and found that when the cutting current was 19 W and 59 W, and the coagulating current was 57 W and 28 W, the depths of the thermal damage into the uterine myometrium were 1.5 mm, 2.7 mm and 6.1 mm, 1.8 mm, respectively. Thus the depths of the tissue thermal damage caused by cutting and coagulating current were different even at the same power.

A clinical and laboratory study of electrothermal effects on tissues during hysteroscopic surgeries was carried out in the Hysteroscopy Center of Fuxing Hospital, Capital Medical University. Based on the study of isolated uterus, different current wave patterns were selected and different electric power and the action time were preset, then electric resection or coagulation was performed on the endometrium and the myometrium hysteroscopically. The tissue specimens obtained after operation were examined by histological and histochemical methods to observe and analyze the correlations among varieties of factors including the electric power, the action time, the thickness of the tissues by cutting or coagulating, and the depth of tissue thermal damages, and to study the histopathologic changes and the depth of electrothermal damages in uterine tissues by electrical thermal effect, as well as to discuss the changes in ultrastructure of cells influenced by the electrothermal effect at the subcellular level under the electron microscope. The aims are to find the appropriate operation power setting and the depth and scope of tissue thermal damage under this set power, and to discuss the action rules and related mechanisms of electrothermal effects on tissues during hysteroscopic surgeries, which can provide references and bases for clinical treatment and the improvement of the safety and effectiveness of hysteroscopic surgery.

5.2.2.1 Influence of Current Wave Patterns on the Thermal Damage to Tissues

In this study, a variety of powers and action times with different currents were set to work on endometrial tissues, it was found that at the same power and the action time, the depth of the tissue thermal damage beneath the cutting electrode was less than that of a coagulating electrode ($P < 0.05$).

5.2.2.2 Influence of Electrode Powers and Action Times on the Thermal Damage to Tissues

It was found from studies of the isolated uterus or hysteroscopic surgery that, (1) at the preset power and the action time, the depth of thermal damage to the tissues beneath the cutting electrode has no correlations to the electric power and the action time ($P > 0.05$); (2) in the isolated uterus, the depth of thermal damage to the tissues beneath the coagulation electrode does not correlate with the electric power and is positively related to the action time; (3) in hysteroscopic surgery, the depth of thermal damage to the tissues caused by coagulating current has significant correlations with electric power and the action time ($P < 0.001$), which is negative with the power and positive with the action time.

The effects of active electrode of different power output on thermal damage depth of uterine tissues can be seen in Tables 5.1 and 5.2.

5.2.2.3 Setting of Electrode Power

There is no uniform standard about the electric power settings in hysteroscopic surgery. The settings of electric powers range from 30 W to 160 W with the power of resection larger than that of coagulation. According to the mechanisms of the electrothermal damage and the clinical requirement on therapeutic effects, a minimum output power should be utilized to achieve the expected therapeutic purpose. The clinical studies in the Hysteroscopy Center of Fuxing Hospital, Capital Medical University indicated that the depth of the uterine tissue thermal damage caused by cutting current was unrelated to the electric power and the action time ($P > 0.05$); when the minimum output power of cutting current was set at 60 W, it could achieve the aim of damaging the whole endometrial layer, but sometimes there might be a phenomenon that the electric wire loop sticks to the endometrium when performing the operation and the speed and the depth of resection might be affected when cutting lasts longer; such phenomenon would be unlikely if the power was increased to 80–100 W, whether the electrode action time is long or short, therefore it was considered a suitable cutting power. The depth of the tissue thermal damage caused by coagulation current is closely correlated to the electric power and the action time. Its correlation could be expressed by regression equation: $Y = 2.666–0.021$ (W) +0.723 (T) ($P < 0.001$), namely, the depth of thermal damage is negatively correlated to power, but positively correlated to electrode action time. In our clinical studies, on the effects of the

Table 5.1 Thermal damage to the isolated uterus and its actual damage depth (mm, $\bar{x} \pm s$)

Type	Power (W)	Cases in total	Endometrium Removal depth	Thermal damage depth Action 3–5 s	Thermal damage depth Action 6–8 s	Actual destruction depth Mean	Actual destruction depth Maximum
Cutting	60	8	2.422 ± 0.106	0.328 ± 0.130	0.516 ± 0.102	3.109 ± 0.126	3.790
	80	10	2.986 ± 0.341	0.375 ± 0.144	0.310 ± 0.082	3.824 ± 0.233	4.262
	100	10	3.325 ± 0.084	0.402 ± 0.121	0.325 ± 0.221	3.819 ± 0.611	4.412
Coagulating	30	8	0.084 ± 0.013	2.643 ± 0.416	3.290 ± 0.422	3.325 ± 0.240	3.948
	60	10	0.132 ± 0.066	2.763 ± 0.162	3.512 ± 0.625	3.610 ± 0.401	4.195
	80	10	0.863 ± 0.147	1.963 ± 0.312	3.020 ± 0.160	3.284 ± 0.138	4.212
	100	8	0.746 ± 0.211	2.041 ± 0.511	2.294 ± 0.242	3.016 ± 0.326	3.884

Note: In the table, the value of the average and maximum damage depth is taken from that of 6 to 8 s groups

Table 5.2 Thermal damage to the uterus in vivo and its actual damage depth (mm, $\bar{x} \pm s$)

Type	Power (W)	Cases in total	Endometrium Removal depth	Thermal damage depth Action 3–5 s	Thermal damage depth Action 6–8 s	Actual destruction depth Mean	Actual destruction depth Maximum
Cutting	60	10	2.047 ± 0.045	0.324 ± 0.125	1.075 ± 0.233	3.081 ± 0.302	3.632
	80	14	2.683 ± 0.216	0.351 ± 0.142	0.536 ± 0.146	3.605 ± 0.423	3.993
	100	12	2.465 ± 0.243	0.447 ± 0.156	0.532 ± 0.186	3.249 ± 0.526	3.920
Coagulating	30	11	0.035 ± 0.007	2.609 ± 0.516	3.474 ± 0.444	3.546 ± 0.520	4.160
	60	13	0.101 ± 0.014	2.533 ± 0.310	3.118 ± 0.537	3.277 ± 0.534	3.788
	80	10	0.362 ± 0.087	1.354 ± 0.318	2.144 ± 0.606	2.514 ± 0.665	3.537
	100	8	0.519 ± 0.239	1.454 ± 0.551	2.106 ± 0.384	2.696 ± 0.485	3.338

Note: In this table, the value of the average and maximum damage depth is taken from that of 6 to 8 s groups

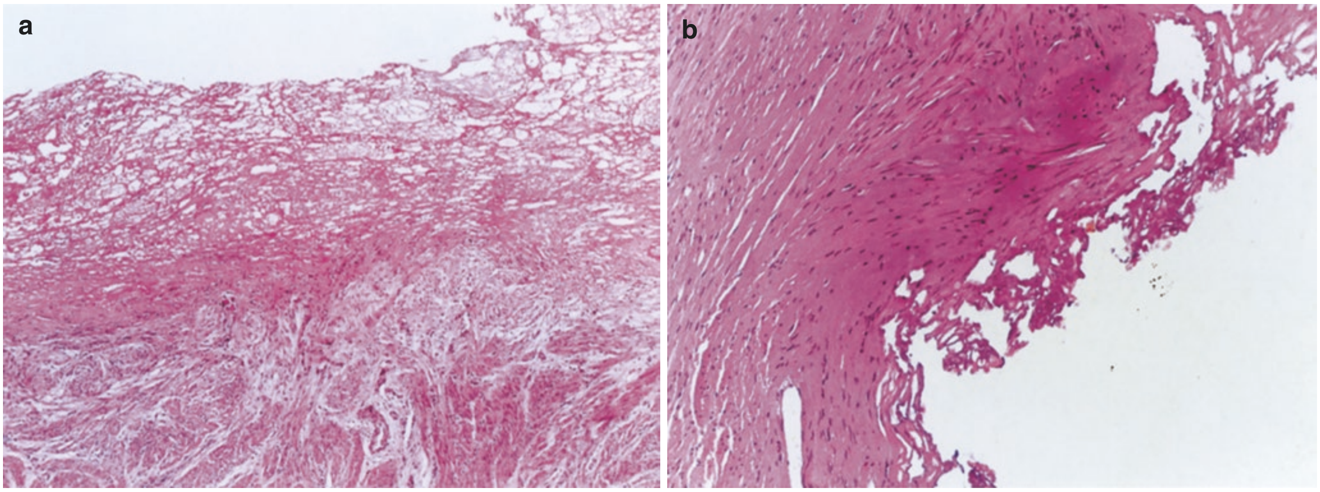

Fig. 5.5 (**a**, **b**) HE staining

four preset coagulation electrode powers on uterine endometrium, respectively, we found that at the same action time, the depth of tissue thermal damage decreased as the power increased; at the same power, it increased as the action time was prolonged. Thus 30–60 W should be a suitable coagulating power. In the clinical operations, when the endometrium is thicker or at a thicker position of the uterine wall, low power active electrode can be used and action time prolongs, thus producing its effect of deep tissue thermal damage. However, if the location is prone to perforation, such as uterine cornua, fundus or a thin uterine wall, the electrode action time should be shortened in order to avoid perforation or even damage to adjacent organs.

5.2.3 Histopathological Changes of Electrothermal Injury

5.2.3.1 Light Microscope

Through light microscopic observation, the pathological changes in thermal tissue damage caused by cutting and coagulation current manifest as a thermal damage zone which is made up of the coagulative and partial muscle necrosis layer from the surface to the inside. The thermal damage zone beneath the coagulating electrode is deeper than that under the cutting electrode.

1. HE (Hematoxylin and Eosin) staining: With HE staining, the coagulative necrosis layer shows that the tissue structure is damaged and cell structure disappears, forming an amorphous eosinophilic pink substance. This layer is thicker in the coagulating group, while thinner in the cutting group, intermixed with blue necrosis nuclear fragments. The characteristics of partial necrosis layer are that the amorphous necrotic cells coexisted with normal cells. Though some cells maintain the normal structure, the eosinophilic cytoplasm is increased, vacuole is formed, cell membrane disappears, and also nuclear pyknosis, karyorrhexis and karyolysis are present (Fig. 5.5a, b).

   The above pathological changes are more apparent in the coagulating group than those in the cutting group. The cutting current does not make any differences in tissue injury at different power and the action time, but in the coagulating group, the less the electric power is and the longer the action time is, the more serious is thermal damage to the tissues.
2. NADH-d (nicotinamide adenine dinucleotide diaphorase) staining: With NADH-d staining, under the action of electrode, the edge of the surface layer with tissue thermal damage appears to be yellowish-brown. A thick colorless tissue strip is visible to the underlying layer. At the bottom layer, the normal uterine smooth muscle cells and the vascular smooth muscle cells are dark blue; between the colorless tissue strip and normal deep blue tissue strip, there is a thin pale blue staining region, which is the transition zone for tissue injuries; the colorless layer of damaged tissue by coagulation is significantly thicker than that by resection, and its thickness is different along with the different power and the action time. The tissue thickness of thermal damage by coagulation is the most at 30 W and the least at 100 W, but the thickness is the most at 80 W and the least at 60 W by resection (Fig. 5.6a, b).
3. Masson's staining: By Masson's staining, the coagulative necrosis layer appears to be orange-red (necrotic smooth muscle), and blue non-cell structure (extracellular collagen fiber) substance. The underlying partial smooth muscle necrosis layer is orange-red denaturized necrotic muscle fibers intermixed with the light blue collagen fibers. At the bottom layer, it is the pink muscle fiber bundles and deep blue intra-bundle collagen fibers (Fig. 5.7a, b).

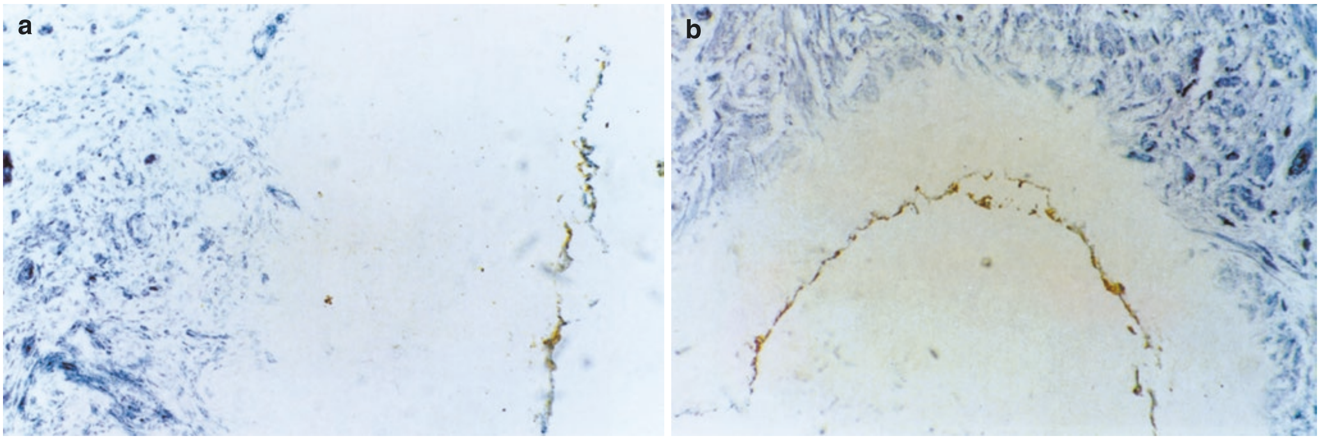

Fig. 5.6 (**a**, **b**) NADH-d staining

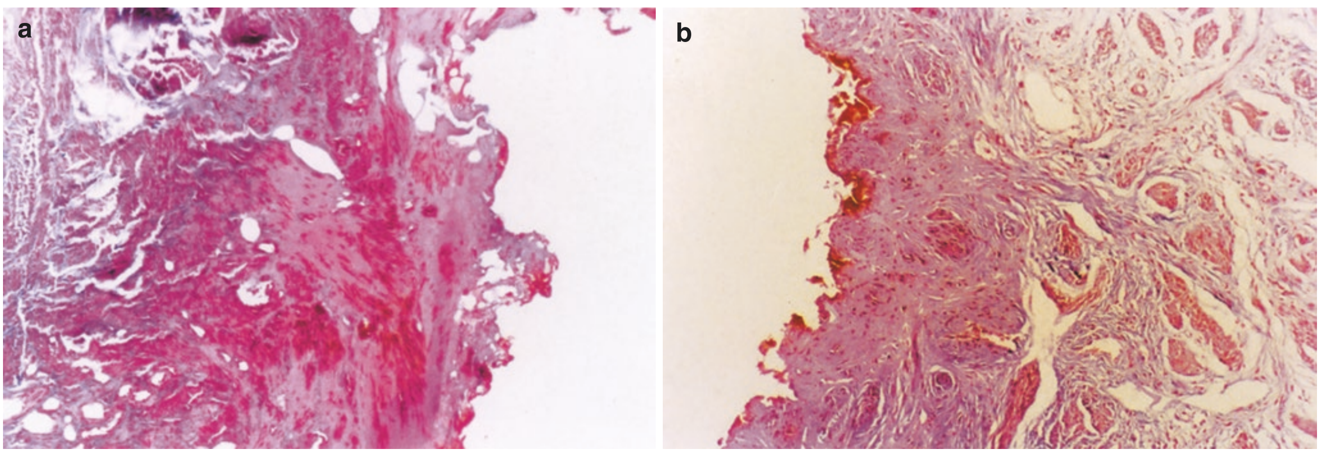

Fig. 5.7 (**a**, **b**) Masson's staining

5.2.3.2 Findings Under Electron Microscope

1. Tissue structure is destroyed by thermal energy, normal cell morphology disappears, only fragments without shapes and structures can be seen.
2. A variety of ultrastructure abnormalities can be seen in transition zone between necrotic zone and normal cells. The changes in nucleus mainly manifest as nuclear pyknosis, karyorrhexis, karyolysis, peripheral clumping of heterochromatin, etc., while in the cytoplasm, vacuoles, mitochondrial swelling, and endoplasmic reticulum expansion and degranulation develop (Fig. 5.8a, b).

5.3 Clinical Application of Hysteroscopic Electrosurgery

After comparing the outcomes of high frequency electrosurgery with laser operations, Gaillard et al. concluded that both techniques were similar, and that the electric energy had its advantages, including being economical and cheap, simple equipment, easy operation, and abundant histopathologic specimens obtained during the operation. Therefore, high frequency electricity has become the superior therapeutic energy source and has been widely used in clinical practice.

5.3.1 Application of Cutting Current in Hysteroscopic Electrosurgery

Cutting current is widely used in gynecological endoscopic surgery. In recent years, hysteroscopic resection of endometrium in treatment of abnormal uterine bleeding has substantially replaced laser endometrial ablation. Cutting current can resect endometrial layer and its underlying superficial myometrial tissues, which can effectively prevent endometrial regeneration. At the time of cutting, if appending some coagulating current, it can effectively coagulate the blood vessels in tissues underneath the cutting surface to achieve a hemostatic effect. Some scholars believed that the clinical effect using cutting current was

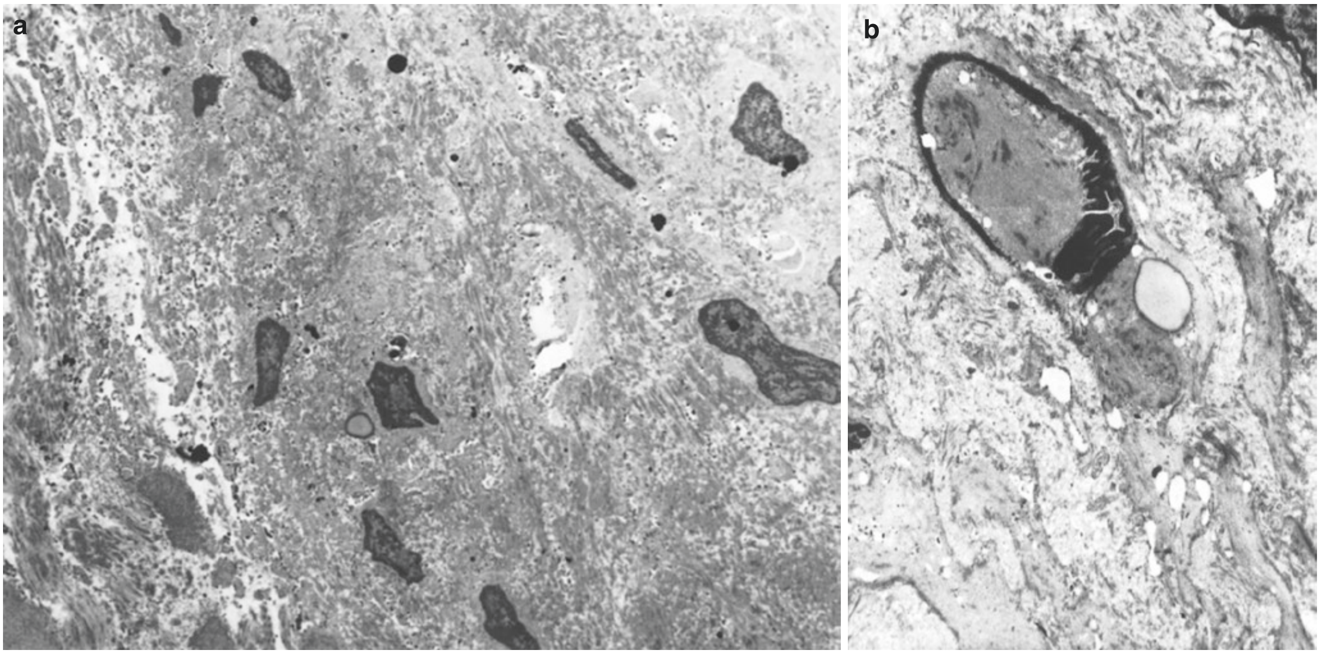

Fig. 5.8 (**a**, **b**) Transition zone between necrotic zone and normal cells

better than that using coagulating current. A cutting electrode could reach directly into the myometrium, which might not only ensure the removal and destruction of the endometrial glands, but also prevent its proliferation effectively. Meanwhile, prior to operation, the endometrium did not need to be pretreated with hormone, which could not only reduce the cost of treatment, but also avoid the side effects of drugs. Almost all the resected endometrial tissues should be taken for histological examination. Some authors reported that some endometrial lesions which were not suspected before the operation were detected from the resected specimens, which included endometrial focal atypical hyperplasia and focal endometrial cancer. This indicated that it helped to reduce the rate of missed diagnosis of endometrial precancerous lesions and endometrial cancer. In addition, the submucosal myoma of uterus and endometrial polyps can be resected continuously, without changing instrument halfway.

Since the uterus is an organ with very rich blood supply, uterine cavity is relatively narrow, and the uterine fundus and bilateral cornual portions have special anatomical and histological features, difficulties are brought about in the intrauterine operations with cutting electrode. In addition, pure cutting current cannot be used directly to coagulate the vessels. Therefore, clinically cutting current is commonly blended with certain coagulating current, which can not only ensure the effective cutting of the benign pathological changes in uterine cavity and endometrium, but also coagulate the blood vessels under the cutting site to achieve hemostasis.

5.3.2 Application of Coagulating Current in Hysteroscopic Electrosurgery

Coagulating current is also an indispensable form of power function in hysteroscopic surgery. Due to its strong thermal penetration, it gets a wide range of tissue damage and good hemostatic effects. Moreover, it is also a relatively simple operation and has small technical difficulty. It is a new approach of treatment for menorrhagia by endometrial ablation resulting from its electric coagulation effects under hysteroscope. Its therapeutic effects are essentially the same as that of laser endometrial ablation, but its postoperative amenorrhea rate is not as high as that by laser. On the one hand the tissue penetrating capability of coagulating current is less than that of laser; on the other hand there are more factors that influencing endometrial destruction by coagulating current, such as the setting of electric power, the shape and the force of the electrode, the action time and the endometrial pretreatment, etc. Thus, the depth of the tissue thermal damage by coagulating electrode is neither as intuitive as the cutting electrode nor easy to evaluate.

Electrocautery, a special form of coagulating current, is mainly used clinically to stop bleeding of a larger area. This electrode uses the higher output voltage of coagulating current to produce spark discharge, at the same time, some of the electrical energy is lost in the form of light. Therefore, it does not have the same depth of the tissue thermal effect as that of coagulating current. Electric spark coagulation is seldom used in hysteroscopic operation.

5.3.3 Application of High Frequency Vaporization in Hysteroscopic Electrosurgery

It is not rare to destroy the endometrium and intrauterine benign lesions in operative hysteroscopy by vaporization principle. However, it is just beginning that vaporization with high frequent electricity is applied in operative hysteroscopy. Since 1980s, laser vaporization has mostly been applied in gynecological endoscopic operation to destroy the lesions. In a comparative study of the removal of endometrium by laser vaporization and high frequency electricity, some scholars found that there was no difference in clinical effects between the laser group and the electrical cutting group. However, due to the complexity of laser equipment, being expensive energy, and failure to obtain specimens for histopathologic examination, it is gradually replaced by cutting and coagulating techniques with high frequency electricity. Compared to cutting and coagulating electrodes, operation by vaporization is relatively simple, easy, and can not only be used to remove larger neoplasm in uterine cavity, but also avoid repeatedly interruption of surgery to take out intrauterine tissue fragments. Furthermore, the electrical energy is cheap and the equipment is easy to use. Hence electric vaporization can yet be regarded as a better method for treatment.

The working principle of high frequency electrical vaporization is similar to that of laser, but the energy source is different. Vaporization current is an undamped current with high power output. Its power setting is well over that of cutting and coagulating current. Vaporization electrode used in hysteroscopic operation is a cylindrical electrode, which has equal spacing grooves. This structure can enlarge the contact areas between the electrode and the tissues, thus increasing the extent of the tissue damaged by the electrode. When the electrode is in operation, the strong output current may generate higher current density inside the contacted tissue with the electrode. Its electrothermal effect can elevate the temperature inside the tissues to vaporization temperature (≥100 °C). Glasser et al. recently reported that by using high frequency current to vaporize the endometrium, the depth of the tissue vaporization might reach 3–4 mm, and by clinical observation, the coagulating range of both the tissues underlying vaporization surface and the surrounding tissues is 1–3 mm. Therefore, a conclusion was drawn that the depth of the tissue damage by vaporization was similar to that by electric cutting. However, in the regions of the uterine cornua or with larger vessels, coagulation with a rollerball electrode is still used so as to avoid uterine perforation and intraoperative hemorrhage. In addition, due to failure to obtain tissue specimens during operation, only when combined with cutting and coagulation electrodes, the vaporization can gain a satisfactory outcome.

5.3.4 Application of High Frequent Bipolar System in Hysteroscopic Electrosurgery

The major difference in monopolar and bipolar circuit system in clinical treatment lies in that they pass through the whole body or local tissues in the current circuit loop. The biggest advantage of bipolar circuit is that it does not need the return electrode plate, and the active electrode is mutually adjacent to the return electrode, the current can only pass through the tissues between them, therefore, the electrothermal effect is relatively limited. Bipolar circuit system is applied quite a lot in laparoscopic surgery, with satisfactory outcomes and low occurrence of intraoperative and postoperative complications. The use of bipolar coagulation system in the treatment of uterine myoma and pelvic endometriosis does not only produce less damage to the adjacent tissues, but also gets better coagulating hemostatic effects, thus rarely causing accidental electric damage to adjacent organs.

Conventional bipolar circuit cannot produce the cutting effect, but the birth of bipolar needle electrode enables endoscopic surgeons to perform effective cutting and coagulation on pathological tissues in the bipolar circuit. The structure of a bipolar needle is shown in Fig. 5.9. The needle electrode is located at the top of return electrode, and the active electrode is 3 mm in length. The current acts on tissues through the active electrode and completes the circle via return electrode.

The animal experimental study by Isaacson et al. indicated that, at the same power output, the effects of both monopolar and bipolar systems on tissues were similar, and there was no difference in thermal damage degrees through their histological evaluations. Since the bipolar system must work in an electrolyte solution, the complications like hyponatremia may be avoided, which is caused by the use of nonionic distending medium. At present, the hysteroscopic bipolar vaporization system has been applied clinically. When the active electrode is activated, a circuit is closed by the electrolyte's ions in distending medium, and the return electrode does not touch the tissues of human body, thus increasing the safety of operation, and harvesting a good prospect of clinical application.

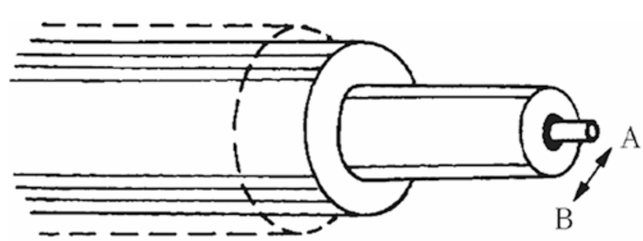

Fig. 5.9 The structure of bipolar needle electrode. (**a**) Active electrode. (**b**) Return electrode

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6 Distention Medium in Hysteroscopy

Limin Feng

Hysteroscopic examination and operation are effective methods for the diagnosis and treatment of the dysfunctional uterine bleeding and other benign lesions in the uterine cavity. The sufficient distention and clear visualization of the uterine cavity is one of the most important factors for examination and treatment, so an appropriate distention medium is necessary for either diagnostic or operative hysteroscopy. The most commonly used distension media include gaseous medium (CO_2), low viscosity liquids (such as glycine, glucose, mannitol or sorbitol, and normal saline), and high viscosity liquids (such as dextran-70). However, due to the serious allergic reactions, the use of high viscosity liquids has already been prohibited. The procedures of hysteroscopic resection are performed under the continuous irrigating of distention media. It is done after the resectoscope being inserted into the uterine cavity through the cervical canal, with both the whole endometrial layer and 2–3 mm myometrial layer underlying the endometrium being resected so as to achieve the aim that the endometrium cannot regenerate. This operation is quite similar to transurethral resection of the prostate (TURP) in that a large amount of liquid distension medium (irrigating fluid) can be absorbed via the intraoperative open veins into the circulation. Furthermore, the uterus is different from the bladder in that the uterus is an organ with certain thickness and a hidden cavity which needs a very high distending pressure. What's more, there is much richer blood supply in the uterine wall than in the bladder wall, so there will be more absorption of distention medium during hysteroscopic surgery than that during TURP, resulting in the syndrome of transurethral resection of the prostate (TURP syndrome). This syndrome leads to the occurrence of hyponatremia, and if not corrected immediately, it could further cause the damage to cardiovascular system, serious neurologic and mental abnormalities, and even death, which are serious complications of endoscopic electro-resection.

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During the hysteroscopic surgery, on the one hand, the uterine vessels are cut off when the endometrium and myometrium are resected, so the distention medium with a certain pressure flows into the body through the open vessel. On the other hand, the distention medium can flow into the abdominal cavity via the fallopian tubes and then is absorbed by the peritoneum, but its absorptive ability seems to be quite little. In many countries, a hysteroscopic surgery is always monitored by laparoscopy. Either laparoscopic suction of the distending fluid flowing into the abdominal cavity via the fallopian tubes at the end of hysteroscopic surgery or intraoperative ligation of both fallopian tubes laparoscopically cannot prevent the complications caused by the absorption of the distention medium, unless the hysteroscopy is complicated by the perforation of the uterus and then a large amount of distention medium flow into the abdominal cavity, which are then absorbed by the peritoneum and lead to a change in electrolytes. However, Istre held that an apparent absorption by the peritoneum might occur within 4 h after operation. The hysteroscopic surgery can also be monitored with ultrasonography, so it can be used to examine the distention medium during the operation, which flows into the abdominal cavity through the opening tubes and gathers in the posterior fornix and then disappears. With years of clinical observation, gynecologists of the Hysteroscopy Center in Fu Xing Hospital, Capital Medical University believed that the amount absorbed via the abdominal cavity is quite little.

The damage caused by the absorption of distention medium firstly raised concern in the 1950s when Creevy reported the first hemolytic reaction resulting from the absorption of the sterile distilled water which was used as irrigating fluid in a patient who had TURP. To prevent this complication, Creevy proposed the idea of using a "non-toxic and non-hemolytic distention medium." The other features of an ideal distention medium are isotonicity and high visualization, and that the increase in plasma and extracellular fluid caused by the absorption of distention medium is temporary and minimum. In addition, a distention medium should not crystallize on the surface of surgical instruments.

E. Xia (ed.), *Practical Manual of Hysteroscopy*, https://doi.org/10.1007/978-981-19-1332-7_6

6.1 CO_2 Gas Insufflation

CO_2 is a colorless gas. It is handy, and its safety can be guaranteed if there is an appropriate gas insufflating machine. Linderman and Mohr reported that there was no complication happened in more than 1200 cases using CO_2 gas insufflation for hysteroscopy. The gas insufflation machine can perfuse gas continuously. After pre-setting the pressure, the flow rate can be automatically adjusted to an optimal state. If the pressure increases, the flow rate could be automatically reduced so as to prevent the complications induced by excessive pressure. The maximum flow rate and pressure in the uterine cavity of CO_2 gas insufflation are 100 mL/min and 200 mmHg respectively, while the most suitable flow rates range between 40 and 60 mL/min, and the most suitable pressures range between 40 and 80 mmHg.

The laparoscopic insufflators must never be connected to a hysteroscope, as they supply the abdominal pressure by L/min, which is far higher than the flow rate of uterine distention (mL/min) for hysteroscopy. The complications of CO_2 uterine distention—tubal rupture, hydrosalpinx and mediastinal rupture—are mainly caused by improper use of gas insufflation machine. Cardiac arrhythmia and cardiac arrest are also reported, which may be caused by too much absorption of CO_2. However, animal experiment models confirmed a wide range of its safety. A large volume of CO_2 entering the abdominal aorta almost did not cause cardiovascular complications, but the endoscopic surgeons should remember to use the minimum flow rate so as to achieve the optimal effect of insufflation.

According to a survey conducted by the American Association of Gynecologic Laparoscopists (AAGL) in 1991, the incidence rate of CO_2 embolism during hysteroscopic surgery was 0.1/1000. Although these cases were not described in detail, it was clear that both the embolism and death occurred in Nd: YAG laser operations cooled by CO_2. The flow rate of CO_2 when it is used for cooling the tip of laser is comparable to that of gas insufflators, which is 500–1000 mL/min. The fact that the CO_2 embolism may cause serious cardiovascular damage and death prompted the FDA to prohibit strictly the use of CO_2-cooled laser in hysteroscopy.

CO_2 is an ideal distention medium for diagnostic hysteroscopy, which can be done with CO_2 distention of the uterine cavity under local anesthesia of the patient. Jong et al. reported that hysteroscopies were performed in 152 outpatients under cervical block anesthesia with 1% lidocaine. Although some patients were extremely nervous, such as nulliparous women and women who had undergone cervical conization, most of them believed that this procedure was durable, and 90% thought that the degree of discomfort was lower than that of dysmenorrhea.

A number of cases proved that CO_2 insufflation could make a clear visualization, with the hysteroscope being directly placed into the uterine cavity through the cervical canal without the requirement of dilating the cervical canal, and CO_2 was insufflated continuously by irrigating through the inflow channel of the hysteroscope from the insufflator. The gas leakage could be prevented by using an appropriate cervical suction cup or holding forceps.

Performing the diagnostic hysteroscopy carefully during the luteal phase can improve the sharpness of the vision, decrease the bleeding and reduce the obstruction of mucus to the vision. Due to the lower refractive index of CO_2, it can make a clear vision, but its magnification is lower than that in the liquid distending media. Moreover, the CO_2 bubbles can be mixed with the blood, which may develop into the foam and affect the vision. In addition, it can make the endometrial debris float in the uterine cavity which leads to the difficulty of sampling. For multipara and patients who have had cervical conization, gas leakage can affect the surgeon's observation so other distending media are strongly suggested.

6.2 High Viscosity Distention Medium: Hyskon

Hyskon is a mixed solution of 32% dextran-70 in 10% glucose, and is produced by the fermentation of bacterial polysaccharides. The average molecular weight of dextran in Hyskon is 70,000, which belongs to a middle-molecular-weight dextran and is a colloidal solution. The dextran developed in 1940s was firstly used in blood volume expansion, which is to expand the blood volume by the absorption of the extravascular water under its colloid osmotic pressure. As a distending medium, Hyskon has the advantage of not mixing with blood. The metabolism of dextran is determined by its molecular weight. The low-molecular-weight dextran (<50,000u) can be filtered by the kidney so only minute quantity may be absorbed; the middle-molecular dextran should be gradually degraded into low-molecular-weight dextran and then be discharged through the kidney; and the high-molecular-weight dextran can be metabolized by the reticuloendothelial system.

It was reported in recent years that the absorption of Hyskon into blood vessels might cause anaphylactic shock and non-cardiogenic edema, and even there was a reported case of instant anaphylactic shock when Hyskon was used. According to the immunology, allergic reactions may be caused by the second encounter with the allergen after the antibody has already been produced by the first contact with antigen. The allergen of Hyskon may be sugar, and cross-reaction may occur with the bacterial antigens, such as streptococcus, pneumococcus, and salmonella. Although the incidence of such kind of anaphylactic shock is quite low, being only 1/10,000, Ahmed et al. reported that three such cases occurred in their hospital during only half a year. The amount of Hyskon administered in these three cases was all <100 mL, and skin test was negative in the postoperative dextran allergic reactions. Moreover, the risk of anaphylactic reaction in allergic patients did not increase compared with that in nonallergic people. As a result, the occurrence of allergic reactions cannot be predicted when dextran is in use.

Most reports of pulmonary edema caused by absorption of Hyskon suggested that it was related to the effect of dextran in pulmonary vessels, and such direct toxicity reaction also occurred when other molecular weight dextrans were in use.

The most possible cause of pulmonary edema secondary to absorption of Hyskon is the increased blood volume. Clinically, dextran has been used as a plasma substitute for the plasma volume expansion, but high-molecular-weight dextran is prohibited in expanding the blood volume. Because dextran has the property of slow metabolism, it can significantly increase plasma colloid osmotic pressure, which can promote a further increase in blood volume, leading to the movement of fluid and electrolytes. Each gram of dextran −70 can carry 20–27 mL of water into the blood circulation, so the absorption of only 100 mL of Hyskon can lead to the expansion of blood volume by 860 mL. Therefore, the blood expanding volume can be ten times more than the amount of Hyskon absorption (e.g. When 100 mL of Hyskon is absorbed into the blood, the blood volume will be expanded by 100 mL of Hyskon and 860 mL of fluid moving from the interstitial space into vessels). However, in the published literatures, it was not described in details about the amount of Hyskon absorption. Therefore there will be fold increases in the blood volume when Hyskon is absorbed, with 350 mL of Hyskon absorption leading to 3.5 L of volume expansion.

Unlike the low viscosity distending fluid, Hyskon does not cause water intoxication, and more specifically, fluid imbalance is secondary to the absorption of colloid osmolytes (dextran) whose half-life may last for several days. Excessive absorption of dextran −70 may lead to the movement of body fluids and electrolytes into vessels, so dextran causes fluid overload by changing the colloid osmotic pressure.

6.3 Low Viscosity Distention Medium

Bradycardia and hypertension may occur in patients with TURP syndrome, followed by hypotension, nausea, vomiting, headache, impaired vision, excitement, mental disorders, and lethargy, all of which resulting from the dilutional hyponatremia and a reduction in plasma osmotic pressure. If not diagnosed and treated in time, they can induce seizures, coma, collapse, and even death. The use of low viscosity distending fluid in hysteroscopic surgery, including glycine, sugar alcohol such as mannitol and sorbitol, is also prone to the occurrence of TURP syndrome, and its incidence is reported at a maximum of 50% and a minimum of 5%.

6.3.1 Research on Complications Induced by Glycine Absorption

Glycine ($CH_2 \cdot NH_2 \cdot COOH$) is a water-soluble small amino acid with the commonly used concentration of 1.5%. And it is hypotonic non-electrolyte solution with the osmotic pressure of 200 mOsm/L. The water intoxication caused by its absorption via the blood vessels appears as hypervolemia and hyponatremia. The incidence of these complications is up to 2% in TURP procedures.

During hysteroscopic surgery, when larger vessels in uterine cavity are cut off, glycine, a distention medium with certain distending pressure, can be absorbed quickly via the open veins. When glycine enters the circulatory system, the serum sodium levels are declined. Under normal circumstances, sodium and other positive ions play a decisive role in plasma osmotic pressure. Rapid reduction in the serum sodium often leads to the prompt reduction in plasma osmotic pressure, but the initial absorption of the glycine molecules contributes to the maintenance of plasma osmotic pressure. However, glycine cannot remain in the blood vessels for long, and the half-life of its molecules after being absorbed into vessels is 85 min. The longer the operative time is and the wider the excised tissues are, the more the glycine absorption will be, which eventually leads to an increase in free water. If this free water cannot be metabolized quickly, hypotonic hyponatremia will occur. Because of the adverse effect of the antidiuretic hormone in hysteroscopic surgery, diuretics are rarely used in surgical procedures. In addition, because of the effect of the female hormone on sodium-potassium adenosine triphosphate anhydride, female patients are more susceptible to hyponatremia, for example, progesterone can inhibit this kind of Na^+–K^+ ATPase in several different tissues.

The dangers of hyponatremia lie in inevitable brain damage, because the water molecules can pass freely through the cell membrane, and quickly establish intravascular, intracellular and extracellular equilibriums of osmotic pressure. Inside and outside the cells, it is easy for water to move from that being hypotonic (high water content) to that being hypertonic (low water content), so that the equilibrium of osmotic pressure is maintained both inside and outside the cells. Water molecules can also pass across the brain barrier freely, and the animal experiments and human observations both confirmed that hyponatremia most easily hurt the brain barrier. Therefore, a rapid increase of free water in vessels will lead to a drop in osmotic pressure and the transfer of water into the brain cells. When suffering from the cerebral edema, brain tissues can be damaged due to the narrow space of the cranial cavity. Increased intracranial pressure can reduce the blood flow velocity, resulting in hypoxia. An increase in the intracranial pressure by 5% can lead to brain herniation, while an increase by 10% can be life-threatening.

Hyponatremia may be an independent factor for TURP syndrome. Na^+ can affect the metabolism of cardiac smooth muscles and skeletal muscles, the release of nerve impulses, cell membrane potential and the permeability of cell membrane. Animal model experiments have confirmed the damage of hyponatremia to the central nervous system. In this study, when the experimental animals got severe hyponatremia under the normal osmotic pressure, they would always been in states of lethargy, twitching, or coma. Thus the authors believed that hyponatremia rather than low osmotic pressure was the main factor for its onset.

In addition to the low osmotic pressure and hyponatremia, another complications induced by glycine are caused by the products of glycine metabolism. The oxidative deamination of glycine is catalyzed by methyltransferase in the liver, forming glyoxylate and ammonia in the kidney. Then the glyoxylate is further metabolized into oxalic acid, forming oxalic acid crystals in the urine. There were many reports on the use of glycine causing hyperammonemic encephalopathy in urologic surgery. If hyponatremia and low osmotic pressure cannot account for patients' symptoms of central nervous system disorders, possibility ammonia poisoning should be considered. The incidence of hyperammonemia in patients with combined preoperative liver disease does not increase. In patients with severe ammonia poisoning, L-arginine can be used to stimulate the ammonia metabolites moving into the urea cycle.

The absorption of glycine may also affect the visual acuity. In a prospective study of 18 patients who underwent TURP, a transient decrease in visual acuity occurred in four patients. It might be caused by the secondary impact of glycine on neurotransmitters, with the formation of the inhibitors of the neurotransmitters in the retinal ganglion and horizontal cells. On the contrary, the blood ammonia levels in the asymptomatic group are significantly higher, which might be due to the fast metabolism of glycine in asymptomatic group. Some scholars have confirmed the significant individual differences in the speed that amino acid is produced through the metabolism of glycine in human body.

Some other scholars reported that glycine, as uterine distention medium, could cause obvious alterations in the function of blood coagulation, which mainly included the reductions of the platelets, fibrinogen, and the erythrocyte binding rate; the extension in partial thromboplastin time and prothrombin time; the presence of fibrin degradation products; a temporary reduction in oxyhemoglobin saturation; and hypercapnia. However, the reasons were not clear. Glycine had been considered as a safe and atoxic distention medium for many years, but the recent literature studies held a negative attitude.

6.3.2 Research on the Complications Induced by Absorption of Sorbitol and Mannitol

Sorbitol and mannitol can also be used as irrigating fluid in hysteroscopic surgery. Cytal, the most commonly used solution, includes 2.7% sorbitol and 0.54% mannitol, and the use of higher concentrations has also been reported. However, high concentrations of sorbitol and mannitol can be melted into caramel under high temperature when doing electric cutting, so it is rarely used clinically. Sorbitol and mannitol are six carbon isomers. Sorbitol is metabolized into fructose and glucose in the liver. Mannitol itself is inactive, only 6–10% can be absorbed and metabolized, and the rests are filtered through the kidney and excreted into the urine as prototype. Therefore, mannitol can produce the effect of osmotic diuresis, which theoretically helps to improve the symptoms of fluid overload and secondary hyponatremia. However, the half-life of mannitol in plasma is 1.5 h in patients with normal renal function, which is unhelpful to fluid equilibrium and recovery of cardiac function. The half-life can be further extended due to the blockage of excretion if patients have kidney disease. The isotonic mannitol 5% has ever been used as irrigating fluid for hysteroscopic surgery in the hysteroscopic center of Fuxing Hospital, Capital Medical University. It was found that the mannitol had the advantage of having the effect of diuresis when it enters the circulation, which might reduce the side effects caused by fluid overload, and it has the drawbacks of both forming a layer of crystal on all contacted surfaces after it is dried and possibly leading to postoperative hypotension after it produces diuresis and dehydration.

6.3.3 Research on the Safety of 5% Glucose as Irrigating Fluid

After years of research, many scholars have believed that an ideal distention medium is supposed to be sterile, non-toxic, and able to maintain the osmotic pressure of an organism; it should have good transparency and not mix with blood, and could ensure a clear operational view; it is non-conductive, low viscosity, easy to prepare, and relatively inexpensive; and its metabolites are very few and harmless. In recent years, the latest progress in hysteroscopic electro-resection with continuous irrigation is to use low viscosity distention media. However, according to the criteria above, those commonly used distention media abroad are not very satisfactory. Since 1990, 5% glucose has been used as distention medium in the Hysteroscopy Center of Fuxing Hospital, Capital Medical University and found:

1. Serum sodium level decreased gradually to the lowest point 1 h after operation and began to recover 4 h later. All changes were within normal range, without any clinical symptoms of hyponatremia.
2. Serum potassium level decreased gradually to the lowest point 1 h after operation, began to recover 4 h later and resumed normal 24 h later. All changes were within normal range, without any change in hypokalemia.
3. The level of blood chloride decreased gradually to the lowest point 1 h after operation and began to recover to normal from 4 h after operation.
4. Blood glucose levels significantly increased to the highest point 1 h after operation and returned to preoperative levels 4 h after operation.
5. The plasma osmotic pressure decreased gradually to the lowest point 1 h after operation and began to recover 4 h later.

The focus of whether 5% glucose can be applied in the irrigation for hysteroscopy lies in the influence of the changes in blood glucose level on the human body. We believe that there is significant increase in blood glucose level after surgery, which is highly correlated with the absorption of the irrigating fluid. If the patients did not have diabetes, the transient hyperglycemia would not produce significant physiological changes. We found that the level of blood glucose began to increase at the end of the operation, and peaked 1 h after operation, and returned to preoperative levels 4 h after operation, which recovered faster than the levels of potassium, sodium, and chlorine. Some scholars doubted that hyperglycemia would cause hypertonic and dehydration, and even aggravate hyponatremia, leading to the symptoms of central nervous system disorders. However, because of the great molecular weight of glucose, its osmotic pressure is limited. If the blood glucose increases by 10 mmol/L (180 mg%), the osmotic pressure will increase by 10 mOsm/L. If the blood glucose increases by 20 mmol/L (360 mg%), the osmotic pressure will increase by 20 mOsm/L. In our study, the maximum level of blood glucose is 469 mEq/L, and in theory, the osmotic pressure should increase by 26 mOsm/L. Animal experiments have confirmed that if the plasma osmolality is >350 mOsm/L, the animals will develop anxiety and irritability; if it is within 375–400 mOsm/L, they will have nystagmus, ataxia, and limb shaking; if it is >400 mOsm/L, they will have startle and develop tonic limb spasms; and if >435 mOsm/L, no animals will survive. Thus even if the plasma osmolality increases by 26 mOsm/L due to hyperglycemia, it does not produce significant pathophysiological changes and the patients do not have any complaints of discomfort according to clinical observations. Animal experiments have also confirmed that there is significant increase in blood glucose level in 5% glucose group, while there is no increase in blood glucose level in 5% mannitol group, but a high mortality. Therefore, high blood glucose is not the cause of death in experimental animals. If a transient increase in blood glucose could lead to a transient increase in plasma osmolality and water movement from the intracellular to the extracellular space, it would be the theoretical basis for some scholars' belief that the glucose as irrigating fluid may aggravate hyponatremia. However, we think this just partially offsets the extracellular hypotonicity and blocks some tendency of water movement from the extracellular space to the intracellular, so a transient increase in blood glucose will not aggravate the reaction of hyponatremia, but reduce the cell swelling and decrease the onset of hyponatremia. Of course, the use of 5% glucose as irrigating fluid for hysteroscopic surgery is not recommended in patients with diabetes and the elderly ones due to their hypoinsulinism.

Some studies suggested that 5% glucose was non-electrolyte solution with the osmotic pressure of 278 mOsm/L which was close to the tension of the blood plasma (280–320 mOsm/L), so it was known as isotonic solution. After being absorbed into the blood, it does not affect the tension in the red blood cells, so the red blood cells will neither swell nor shrink, but maintain its original integrity. However, glucose in the body is soon oxidized to CO_2 and H_2O, and supplies the energy at the same time, or it is stored in liver cells in the forms of glycogen, both of which leading to the loss of the original tension. Therefore, 5% glucose solution is isotonic solution apparently, but it can be used as tension-free solution due to its shortly-lasting tension in the body. Glucose returns to preoperative levels 4 h after operation, so the high metabolic rate would not cause the pathophysiological changes in the body.

Two phase contrast ultrasonography is applied in the monitoring of the whole surgical process of hysteroscopy. That is, the bladder is filled and the distention medium is injected into the uterine cavity, and strong echogenic band of light is formed under the high-frequency electric effect on the inner wall of the uterus. This unique change in the sonogram is an effective indication for ultrasonography monitoring of intrauterine electro-resection. Meanwhile, it is found in some patients that the irrigating fluids infiltrating into the muscle wall present cloudy strong echo, forming a special ultrasonic image (Fig. 6.1). A statistical analysis has been made for this phenomenon. According to other scholars' research, adverse effects may occur when absorption of distention medium is >900 mL, so we also took this as the standard. The result showed that in patients with infiltration of distention medium revealed by ultrasonography, there was a significant increase in the absorption of the distention

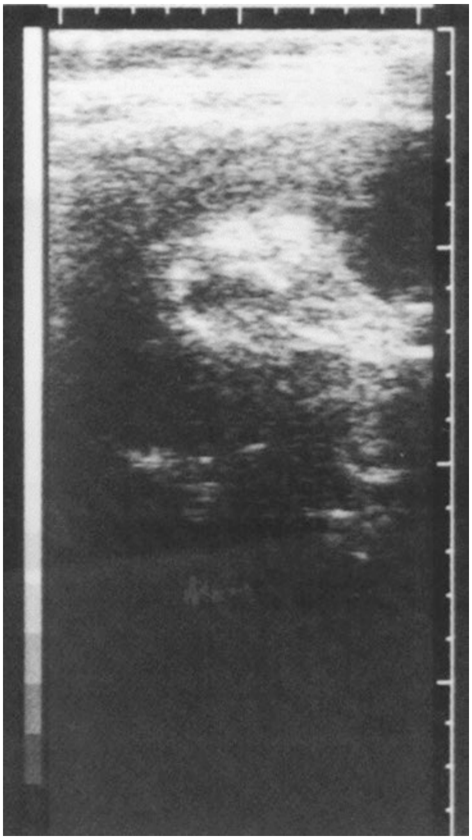

Fig. 6.1 The irrigating fluid infiltrates into the muscle wall, presenting cloudy strong echo under ultrasonography

medium. It was thought that such patients may have adenomyosis. The formation of strong echo when irrigating fluid infiltrates into the muscle wall may result from the direct extension of the basal endometrium into the myometrium and the reactive hyperplasia of uterine muscle fibers. If the glandular tubes in the muscle wall communicate with the uterine cavity, under ultrasonography, the irrigating fluid can be seen infiltrating into the focal areas of the uterine wall, and the bubbles can be detected accumulating in the cavity below the anterior wall, thus forming a special ultrasonic image. This is also another way of distention medium absorption, which cannot be neglected and needs to be further studied and confirmed.

6.4 Etiology and Clinical Presentation of TURP Syndrome

6.4.1 Etiology of TURP Syndrome

TURP syndrome has been the most serious complication of transurethral electro-resections. It refers to a series of symptoms in the whole body caused by hypervolemia and hyponatremia, which results from excessive absorption of irrigating fluid into the blood circulation. Though very rare, it may lead to a death rate of 15–40% once occurring. Early in 1946, Greevy et al. reported that, during a transurethral electro-resection, the distilled water was used as irrigating fluid, which entered blood circulation through the open veins caused by resection and increased the blood volume rapidly in a short time, leading to the destruction of large numbers of erythrocytes and then production of great quantities of hemoglobin, which finally resulted in impaired renal function. Afterwards, many scholars conducted the experimental studies by injection of the hemoglobin into the blood of animals, and the results showed that a large amount of hemoglobin in blood circulation did not cause impaired renal function. And when hemoglobin 50 g was injected into blood of human body at one time, it would be completely discharged out of the body after 30 h, causing no damage to the renal function. In 1955, Hagstrom firstly named transurethral resection of the prostate syndrome (TURP syndrome), described the typical clinical symptoms, and pointed out clearly that the true cause of the syndrome was the sudden decrease in plasma sodium. After more than 20 years of clinical practice and research, the mechanism of TURP syndrome has been clearly understood theoretically. Among them, Guy et al. conducted quite a lot of animal experiments and clinical observations and confirmed that the cause of TURP syndrome when glycine was used as distention medium was neither hyperammonemia nor low osmotic pressure hyperlipidemia, but hyponatremia. The clinical manifestations of TURP syndrome are bradycardia and hypertension secondary to hyponatremia, followed by hypotension, nausea, vomiting, headache, impaired vision, excitement, mental disorders, and lethargy. If not cured immediately, it can result in cerebral edema, herniation, leading to seizures, coma, collapse, and even death. All these symptoms are caused by dilutional hyponatremia and hypervolemia. And it is also suggested that the low osmotic pressure is also one of the causes of this syndrome.

To verify that a transient hyperglycemia does not aggravate hyponatremia, the researchers in the Hysteroscopy Center of Fuxing Hospital, Capital Medical University designed an animal experiment, the results were as follows:

1. There was a drop in plasma sodium in Wista rats of 5% glucose group, 5% mannitol group and the balanced solution group, and the most significant drop was in mannitol group.
2. There was an increase in plasma potassium levels in all three groups, and the most significant increase was in mannitol group.
3. There was an increase in plasma chloride levels in three groups, and the most significant increase was in mannitol group.

4. There was an increase of varying degrees in the blood glucose level in three groups, and the most significant increase was in glucose group.
5. There was a drop in plasma osmotic pressure in three groups, and the most significant drop was in mannitol group.
6. Status of animal survival: 2 died within 1 h and 4 died within 2 h in the group of 5% mannitol, 1 died in the group of 5% glucose, and 14 died in the group of mannitol within 24 h.

In recent years, the use of low viscosity uterine distending medium during hysteroscopy with continuous irrigating has been more and more advocated. The most frequently used media abroad are 1.5% glycine, Cytal solution and 5% mannitol. There is no 1.5% glycine and Cytal solution available in our country presently, so 5% mannitol and 5% glucose are used in our study.

As to the research on low viscosity fluid, it is found that 1.5% glycine cannot only easily lead to TURP syndrome, but also cause an increase in blood ammonia levels by its metabolites, resulting in a series of neurological and psychiatric symptoms and a transient decrease in visual acuity, which has been increasingly concerned by the hysteroscopists. The deep studies on the application of 5% mannitol as the irrigating fluid in the hysteroscopic resection are obviously inferior to that of 1.5% glycine. Although complications of water intoxication and hyponatremia induced by mannitol are similar to those of 1.5% glycine, only 6–10% of mannitol are absorbed and metabolized due to its inactive ingredient, and the rest is filtered by kidney and excreted into the urine as prototype. Therefore, mannitol can produce an effect of osmotic diuresis, and theoretically helps to reduce the dangers of the fluid overload and secondary hyponatremia. Thus Arieff believed that the isotonic mannitol was the most suitable for irrigating during electro-resection because it is nonconductive with only a little amount being metabolized in the body and will not cause a change in low osmotic pressure. However, the animal experiment confirmed the fact that the severity of hyponatremia, hypokalemia, low chlorine, and low osmotic pressure caused by the absorption of 5% mannitol was significantly higher than that of 5% glucose group. With respect to the recovery of animal behavior and survival rate, there was also significant difference between two groups. In addition, these experimental results showed that there was an obvious increase in blood glucose only in the group of 5% glucose, which confirmed that the increase in blood glucose would not increase the reaction of hyponatremia and mortality of animals. Therefore, the researchers believed that application of 5% glucose in hysteroscopic electro-resection was superior to 5% mannitol with regard to biochemical changes, the economic burden, the convenience of preparation, or the confirmation of clinical observations.

Surgical treatment of intrauterine disorders has become a trend in gynecological surgery, which has greatly decreased the administration of hysterectomy in many developed countries. In the past, 20% of the patients with dysfunctional uterine bleeding (DUB) needed to undergo hysterectomy, but hysteroscopic surgery can cure or effectively reduce the irregular vaginal bleeding in 80–90% of patients with DUB. In addition, treatment of uterine septum, submucous myoma, and intramural myoma can achieve therapeutic purposes without laparotomy so as to avoid the short-term and long-term complications caused by open surgery. The hysteroscopic surgery has fewer complications, shorter operative time, and shorter length of hospital stay and rapid recovery after operation. Since a high viscosity uterine distending medium may cause serious complications such as allergic-like reaction, non-cardiogenic edema, and coagulation disorders, nowadays people tend to use low viscosity uterine distending media which have fewer complications. The most frequently used distending medium abroad is 1.5% glycine, but the occurrence of hyponatremia has increasingly caught people's attention. Recently, there have also been continuous reports on hyperammonemia or death caused by great amounts of absorption of 1.5% glycine.

As to the application of 5% glucose as irrigating fluid in hysteroscopic electro-resection, there have been 13 cases reported by Lin about hysteroscopic resection of submucous myoma, but without any discussion on its safety. Sandra et al. performed hysteroscopic surgery using 5% glucose as the distention medium on four patients experimentally in the year of 1989, and the results discovered that all four patients developed hyperglycemia, with 2 of whom associated with serious hyponatremia. Therefore, it was believed that high blood glucose could aggravate hyponatremia. However, after analyzing Sandra's study, we believe that the distention pressure up to 150–250 mmHg they used was the inevitable reason for the aggravation of hyponatremia in patients. According to many years' research on hysteroscopic electro-resection, some scholars thought that the best distention pressure was 60 mmHg. However, Quinones declared that the bilateral tubal ostia could not be seen until the intrauterine pressure was raised to 100–110 mmHg. However, it is generally acknowledged by most scholars that the intrauterine pressure should not be higher than 100 mmHg, and even some scholars thought that there would be rare complications if the distention pressure was <100 mmHg.

We used 5% glucose as irrigating fluid in various hysteroscopic intrauterine operations, and found no TURP syndrome occurred, even in women complicated with renal failure, kidney transplantation, heart failure, cardiac valve replacement surgery, blood diseases, and so on. Amratage held that the procedure of hysteroscopic electro-resection should be stopped if the absorption of irrigating fluid was more than 1000 mL. However, in our study, the largest volume of irrigating fluid absorption was 1520 mL, and no hyponatremia was found to occur by either clinical observation or biochemical tests. With the measurements of the plasma electrolytes, blood glucose and plasma osmotic pressure and a contrast study conducted with 5% mannitol, it was further confirmed that 5% glucose used as irrigating fluid in intrauterine surgery was safe and economical, and was worthy of popularization. Of course, in order to avoid excessive fluid absorption, the operative time should be shortened as much as possible and the irrigating pressure should be controlled. If the infiltration of fluid into the uterine muscle wall was detected during operation, the absorption of irrigating fluid and the electrolyte balance should be closely monitored. In addition, close observation after operation should be done so as to avoid the occurrence of electrolyte disturbances post-operation.

6.4.2 Clinical Presentation of TURP Syndrome

The pathophysiological changes of TURP syndrome are dilutional hyponatremia and acute hypervolemia, with the clinical presentations mainly appearing as increased heart rate and increased blood pressure; lowered blood pressure, nausea, vomiting, headache, blurred vision, restlessness; dyspnea, pulmonary edema; arrhythmia, decreased heart rate, elevated CVP, heart failure, and hemolysis. Then, there may be more serious dyspnea, metabolic acidosis induced by excessive lactic acids produced by tissues; and shock due to worsened heart failures. Ventricular arrhythmias, mental confusion, lethargy, and death may follow in severe cases.

6.5 Treatment of TURP Syndrome

The treatment of TURP syndrome includes monitoring of the vital signs, management of disorders such as hyponatremia, heart failure, pulmonary edema, and cerebral edema, and correction of electrolyte disturbance and acid-base imbalance.

6.5.1 Treatment of Hyponatremia

Treatment of hyponatremia is aimed at potent diuresis and sodium replacement.

The precautions in the use of potent diuretics are: pay attention to its dosage, which can be decided through measurement of the hemoglobin content and relative density of urine, and through measurement of the central venous pressure as well. And attention should also be paid to serum electrolytes for prevention of hypokalemia.

6.5.1.1 Calculation of the Serum Sodium Deficit

$$\text{Sodium replacement required} = \left(\text{normal sodium} - \text{Patient's sodium}\right) \times 52\% \times \text{kg body weight}$$

52% refers to the ratio of person's body fluids to the total weight.

6.5.1.2 Key Points in the Replacement of Sodium

1. Rapid and high concentrations of intravenous sodium replacement should be avoided.
2. During the acute phase of hyponatremia, the replacement rate with serum sodium ions increased by 1–2 mEq/L per hour can relieve the symptom.
3. Increase in plasma osmotic pressure cannot exceed 12 mOsm/L in 24 h.
4. Dynamic monitoring of blood electrolytes and urinary output is needed.
5. Usually hypertonic saline solutions should not be used to correct hyponatremia, but correction with normal saline could be extremely effective. Generally, 1/3 or 1/2 of the sodium deficient is given at first so as to increase the osmotic pressure of extracellular fluid, transfer the water from the intracellular to extracellular space, and restore the cellular function. Observation of the patient is made for half an hour, which includes consciousness, mental status, blood pressure, heart and lung function, and serum sodium concentration. Those are basis to determine the replacement amount of the rest deficient, when hypertonic saline is always used.
6. Sodium replacement can just maintain serum sodium concentration at 130 mEq/L (mild hyponatremia).

Some authors believed that the best treatment for the body fluid overload was to restrict water intake and promote spontaneous diuresis, especially when patients had no obvious symptoms. This treatment may be inappropriate for patients with severe hyponatremia, which may lead to rapid deterioration of the symptoms. Arieff and Ayus reported that symptomatic hyponatremia occurred in 15 women who underwent surgery. Eight of the patients developed epileptic seizures and respiratory inhibition without any warning. Because there is usually no warning before the attack of these serious symptoms, immediate intervention should be taken. However, there is still much dispute over what is the proper therapy. The consensus of the researchers is that the serum sodium level should be corrected, but the correction rate has always been the focus of dispute. Rapid correction of sodium may lead to an intractable brain damage—central pontine myelinolysis (CPM). CPM refers to a phenomenon that after correction of hyponatremia, the symptoms of which would be firstly improved, but several days later, the patients' neurological conditions may worsen, and the new clinical symptoms are completely different from the original symptoms caused by hyponatremia, which can even lead to death. CPM was firstly defined and described by Adamas et al.

As CPM progresses, patients may develop spastic quadriplegia, aphasia, pseudobulbar palsy, behavioral impairment and movement disorders. Although the onset of symptoms may occur 4 h after surgery, CT and MRI can help to make diagnoses in the early stage of pathological process. Autopsy ascribes the destruction of myelin sheath at pons and outside the pons. In order to describe this pathological process more accurately, Arieff recommended the name of "demyelination disorders." Animal experiments have confirmed that too rapid correction of chronic hyponatremia can lead to brain demyelination, but gradual correction may prevent this disorder.

Brain demyelination disorders induced by rapid correction of hyponatremia are the corresponding pathological changes in brain tissues secondary to changes in osmotic pressure. The brain can relatively resist osmotic swelling, because when the intracranial pressure rises, the brain tissue can discharge water into the cerebrospinal fluid. The capacity to drain water and avoid osmotic swelling is time dependent. In patients with hyponatremia, as the pressure in the inter-tissue space increases, water is released into the cerebrospinal fluid by the effects of osmosis. Almost at the same time, the sodium and water is forced into the cerebrospinal fluid through the extracellular channel, so the liquid then enters the central nervous system. Secondary disorders of the brain occur at the cellular level. Unlike other tissues, brain cells discharge intracellular solute in a hypotonic state. Intracellular K^+ moves with the water from inside the cell to outside the cell within 3–4 h, and this movement may reach a peak within 24 h. A few days later, there may be a loss of the cytoplasmic organic solutes (formerly called as "spontaneous infiltration"), including taurine, creatine phosphate, and glutamate, and so on.

This adaptation to hyponatremia and low osmotic pressure can account for the changes of the brain in the rapid correction of hyponatremia. In order to reduce the swelling, the brain tissue achieves balance with plasma osmotic pressure by reducing the intracellular solute content. If the plasma osmotic pressure increases quickly, the brain tissue will dehydrate, because the rapid increase in osmotic pressure can lead to transfer of water from brain cells into plasma, causing brain dehydration.

Plasma osmotic pressure cannot be corrected rapidly because the intracellular spontaneous infiltration and K^+ release will last for a few days. Moreover, these ions re-enter the cells more slowly than being discharged. CPM is considered to be caused by brain cells "shrinkage" due to the rapid correction of hyponatremia. Thus, CPM is also known as "osmotic demyelination syndrome."

In addition, it is worthwhile to note that the mortality of acute hyponatremia is much higher than that of chronic one. When the serum sodium level is 120 mmol/L, acute hyponatremia can lead to death, while the chronic one would not. If the low sodium state lasts for 48 h, it can be recognized as chronic. Within 48 h, the brain cells can balance the hypotonic state through the release of solute. In an acute state, a rapid correction of serum sodium rarely causes damage, because no "shrinkage" is developed in brain cells. Animal experiments showed that a rapid correction of serum sodium within 24 h was feasible and would not cause either the "shrinkage" of brain cells or demyelination disorders. However, the same treatment for hyponatremia 3 days later can lead to the "shrinkage" of brain cells, demyelination disorders, and death.

Hyponatremia induced by hysteroscopic surgery is an acute process. Close intraoperative and postoperative monitoring, timely diagnosis, and advance treatment should be administered, and it is not appropriate to limit the fluid intake solely and wait for spontaneous diuresis. Rapid correction in serum sodium levels often leads to overcorrection, and the use of diuretics can usually cause hypernatremia. Minor increase in plasma osmotic pressure can offset the hazards of cerebral edema. Assuming that the serum sodium concentration drops to 120 mmol/L, and if it is raised to 126 or 132 mmol/L (increase rate 5–10%), cerebral edema could be effectively relieved. The serum sodium concentration can be raised from 1 to 2 mmol/L per hour in the first several hours and an increase in serum sodium concentration within the first 24 h should be <12 mmol/L. If hyponatremia is not diagnosed in the postoperative 24–48 h, subsequent treatment must be implemented cautiously so as to avoid CPM. If a large amount of irrigating fluid was absorbed via peritoneum, a series of symptoms of hyponatremia would be delayed, including cerebral edema.

To prevent the development of CPM in the treatment of chronic hyponatremia, some scholars believed that the serum sodium level could be raised by <25 mmol/L within first 48 h of treatment. Similarly, some scholars held that the correction rate of serum sodium should not exceed 12 mmol/L per hour. It is unnecessary to pursue the normal serum sodium level at the risk of overcorrection, and it is appropriate just to reach the level of mild hyponatremia. The correction rate per hour is still controversial currently. Earlier reports suggested that serum sodium levels should be slowly corrected, and the correction rate per hour be <0.6 mmol/L. Other reports indicated that the hourly rate of correction was not important, but excessively slow correction of the brain status could also lead to death.

In the treatment of acute hyponatremia, there are many different ways, including intravenous infusion of normal saline, 3–5% sodium chloride and potent diuresis. Hypertonic saline with concentration more than 5% is strictly prohibited, which may worsen the body fluid overload further. Some scholars advocated substituting furosemide or mannitol for diuretics, of which mannitol was preferred due to osmotic diuresis, and very small quantities of Na^+ in the urine might be lost. However just as hypertonic saline, mannitol is an effective intravascular osmotic agent, which can also cause unnecessary increase in blood volume. For this reason, some people advocated the use of furosemide. The diuretic effect can work a few minutes after intravenous infusion of furosemide. 20 mg is sufficient to achieve the diuretic effect in patients with normal renal function, but large doses of furosemide are required for patients with renal insufficiency. The amount of urine and urine sodium content should be accurately calculated, and a proper blood volume should be maintained in the treatment.

6.5.2 Treatment of Acute Heart Failure

The patient is placed in a semi-sitting position, and digitalis preparation is needed in addition to diuretics. Its principles are to strengthen the cardiac contractility so as to increase the cardiac output and slow down the heart rate, and to promote peripheral vasoconstriction and hepatic venous contraction so as to reduce venous return. Dosage: lanatoside C: 0.4 mg, slow intravenous injection; digitalis preparation: 1.0–1.2 mg, slow intravenous injection.

6.5.3 Treatment of Pulmonary Edema

1. Treatment of hypoxemia: Oxygen uptake through nasal catheter is given at a flow rate of 6 L/min; mask oxygen inhalation is administered to patients with obnubilation. If the above-mentioned treatment is ineffective and PO_2 is under 50 mmHg, trachea cannula is suggested. If the intermittent positive pressure breath at the beginning is still ineffective, positive end expiratory pressure is recommended so as to increase the functional residual capacity and effectively prevent the expiratory alveolar collapse. Application of defoaming agent: during the oxygen uptake through nasal catheter, 75–95% ethanol is put into the filter bottle and taken in together with the oxygen, while 20–30% alcohol used in mask oxygen inhalation.
2. About morphine: Morphine is suggested for patients with heart failure and lung edema due to other causes. However, it is not appropriate if lung edema is caused by TURP, because morphine may lead to the release of ADH (antidiuretic hormone), which reduces urine output, aggravating water intoxication.

6.5.4 Treatment of Cerebral Edema

1. High concentration urea—osmotic diuretic: Intravascular fluid osmotic pressure is higher than that in tissues, thus water enters from brain tissue into the blood vessels.
2. Corticosteroid hormone—dexamethasone: It may stabilize cell membrane, reduce capillary permeability, and relieve cerebral edema.

6.5.5 Correction of Electrolyte Imbalance

1. Hypokalemia: Excessive use of diuretics may cause low potassium and arrhythmia, serum potassium should be measured, and ECG monitoring should be taken.
2. Metabolic acidosis: pH value is measured and intravenous drip of 4% sodium bicarbonate injection is administered.

6.6 TURP Syndrome: Prophylactic Measures

Clinically, there are many effective ways to prevent excessive absorption of the distention medium. First of all, no matter what kind of distention medium is in use, the absorption should be closely monitored intraoperatively, and the volume of fluid input and output must be accurately measured. An resectoscope with double channels (i.e. the fluid inlet channel and the outlet channel are separated) should be used in surgery, which can effectively allow outflow of the fluid accumulating in the uterine cavity and also help drainage the fluid with vacuum aspiration. If not combined with laparoscopic monitoring, the surgery under non-general anesthesia is helpful in the observation of the complications, such as nausea, vomiting, and altered mental status which may be suggestive of hyponatremia and foamy sputum which may be suggestive of pulmonary edema. Moreover, the low temperature irrigating fluid can stimulate vascular contraction and reduce the absorption of distention fluid. If hysteroscopic resection of uterine fibroids is to be undertaken, preoperative administration of GnRH agonists can reduce the size of myoma and decrease the blood flow, which can be helpful to shorten the operative time and lower the volume of irrigating fluid. Finally, although the operative time is closely related to the absorption of irrigating fluid and hyponatremia, many scholars believed that the operation should be terminated when excessive absorption of fluid was threatening the safety of the operation, and another time should be selected for a second operation.

6.6.1 Prevention of Complications Caused by High Viscosity Distention Medium

The irrigating pressure of Hyskon, which is a high viscosity distention medium, should not be higher than 150 mmHg. Pulmonary edema occurs when the input volume is >500 mL, so the absorption volume should be limited within 300 mL. The absorption volume of 300 mL can increase the blood volume of 2900 mL, so the operative time should be less than 45 min when Hyskon is used as distention medium.

6.6.2 Prevention of Complications Caused by Low Viscosity Distention Medium

When low viscosity distention medium is used, such as glycine and mannitol solution, the absorption volume of fluid is easy to be underestimated, because the irrigating fluid usually leaks from the cervix and the leaked fluid is often underestimated or over calculated. Therefore, an accurate method of surveillance is needed. In order to monitor closely the balance of body fluid, many scholars suggested adding ethanol into the irrigating fluid to measure the ethanol content in breathing so as to calculate the absorption of irrigating fluid.

In TURP syndrome, the amount of irrigating fluid absorption is related to the weight of resected tissues and the duration of operation and the pressure of distention. In hysteroscopic surgery, the absorption of irrigating fluid is related to the intrauterine pressure, so the pressure should be confined to that achieving a clear vision. Mclucas held that the distention pressure should be limited to 60 cm H_2O (44 mmHg). Istre et al. believed that it could be considered as safe if the pressure was lower than 100 mmHg. Moreover, some scholars believed the highest pressure in the uterine cavity should be matched with the patients' blood pressure. The same irrigating pressure can produce different intrauterine pressure, which is also very important. Vulgaropulos et al. discovered that the intrauterine pressure could continue to be at a low level if the fluid outlet pipe remained to be open intraoperatively. On the contrary, if the fluid outlet pipe was closed and the height difference of the fluid was 2.44 m (8 ft) and 4.27 m (14 ft), the intrauterine pressure would be 230 and 280 mmHg, respectively. However, the author did not think this pressure would lead to absorption of fluid since it only lasted for 30—60s, and the author did not describe clearly what operative procedures were done under these pressures. Some authors suggested keeping the fluid output pipe unobstructed and the intrauterine pressure at 60–75 mmHg, which would be helpful for prevention of the fluid absorption. More attention should be paid especially when the extent of surgery became greater.

When low viscosity distention medium is used, if the absorption volume is greater than 500 mL, the surgeons should closely observe the conditions of the lungs and check the levels of serum electrolyte. The amount of fluid absorption should be accurately measured by the intake and outflow volume. Some scholars reported that there was an average decline in serum sodium concentration by 2.5 mEq/L (0–10 mEq/L)when the absorption volume of glycine was <500 mL, and there was an average decline by 8 mEq/L (0–25 mEq/L) when the absorption volume was >500 mL. In this research, the absorption volume in two patients was 2300 and 2700 mL, respectively, while the decrease in serum sodium was 16 and 25 mEq/L, respectively.

6.7 Equipment for Uterine Distention with Fluids

In order to continuously monitor the inflow and the absorption volumes of the fluid, the Olympus Cooperation designed and produced a continuous flow irrigation pump. Its operational principle is that the low viscosity irrigation fluid enters the uterine cavity through a rotating pump via resectoscope, the pressure and flow rate of the pump can both be previously set. The fluid flowing out of the uterine cavity is collected in a container with scales. The difference between the inflow and the outflow is the amount of absorption. These figures are all displayed on the screen of the monitor. If the amount of absorption is more than a certain standard volume (usu. 1 L), the pump should sound the alarm in order to remind the surgeon to terminate the operation immediately.

The distending pressures of the pump range from 0 to 150 mmHg, and the flow rate range from 0 to 450 mL/min. According to our experience, the pressure should be set at 100 mmHg and the flow rate at 200–250 mL/min, the average intrauterine pressure could be at 70–75 mmHg. If the effect of distension is not satisfied, leading to a blurry operation field, the pressure can be set lower than the patient's systolic arterial pressure according to the blood pressure. Low pressure and high flow rate are the guarantee of safe hysteroscopic electro-resections.

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7 Anesthesia for Hysteroscopy

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Hysteroscopy is a new technique for treatment of gynecological diseases which was developed in 1990s. It integrates optical fiber, photoelectricity, mini camera, image analysis, and imaging as a whole. When these high-tech instruments are in clinical use, due to its characteristic technique, adverse effects and severe complications may occur. Therefore, anesthetists must have sufficient knowledge related to this field and possess emergency treatment skills to deal with intraoperative accidents and complications.

7.1 Pre-anesthetic Assessment

Although the pre-anesthetic assessment of hysteroscopy is very similar to that of other surgery, large quantities of epidemiological studies showed that inadequate preparation before surgery was one of the main causes of postoperative complications and death. The saying "There is only a minor operation but no minor anesthesia" admonishes people to administer anesthesia cautiously and more importance should be attached to the pre-anesthetic assessment. The pre-anesthetic assessment should be conducted as follows.

7.1.1 Preoperative Visits on Patients and Participation in Preoperative Discussions

One to three days before the surgery, the anesthetist should go into the ward to visit the patient or participate in preoperative discussion. An anesthesia outpatient clinic should be established in hospitals with better conditions so as to conduct a pre-anesthetic assessment. This helps to establish the patient's senses of security and trust, relieve the possible physical and psychological damage to the patient caused by fear and tension, and also figure out the operation site, method, scope and position so that the anesthetic method, equipment, and pharmaceutical preparations can be determined. The patient should be told not to eat and drink 8–12 h before surgery, and both the patient and her family should be informed of the dangers of anesthesia, especially the occurrence of an anesthetic accident, which might endanger the patient's life. Their understandings and written signatures should be obtained before the surgery. As the legal system in our country has been gradually perfected, some hospitals have already implemented a notarized signature on the consent for anesthesia, which is helpful in the implementation of anesthesia.

7.1.2 Getting Familiar with the Patient's Medical History and Conducting a Systematic Physical Examination

The anesthetist must be especially clear about the patient's history of present illness and whether there is concomitant medical diseases, such as heart disease, hypertension, diabetes, liver and kidney disease, asthma, anemia, blood diseases, blood coagulation disorders, and anticoagulant therapy, whether they are already cured or still being treated, what medications are used, the therapeutic reactions, any history of drug allergy, which are directly related to the safety of anesthesia. Much importance should be attached to the past history and family history, like whether the patient has received anesthesia or not, its frequency, mode, and effect, and whether her family has had hereditary diseases, myasthenia gravis or malignant hyperthermia, which is directly related to the effects of anesthesia and prognosis. Therefore, the patient's general conditions must be systematically examined before surgery, including vital signs, heart and lung auscultation, extremities and spine, and nervous system so that an anesthetic plan can be determined.

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E. Xia (ed.), *Practical Manual of Hysteroscopy*, https://doi.org/10.1007/978-981-19-1332-7_7

7.1.3 Examining and Checking the Essential Laboratory Parameters

1. Routine blood and urine test: It is mainly to find out whether the patient is anemic or not, and the degree of anemia and functions of the kidney.
2. Biochemical examination: It is to focus on the liver function, plasma protein, and albumin/globulin ratio, and serum concentration of potassium, sodium, and glucose. Some medical treatments like cardiotonic, diuretic, and hypoglycemic can lead to electrolyte imbalance.
3. Electrocardiogram (ECG) and chest X-ray: ECG and chest X-ray are to understand the cardiac electrophysiological activity, myocardial blood supply, and lung condition.
4. Other special examinations: Patients with heart and lung diseases should undergo examination of lung function, cardiac echocardiography, and blood gas analysis when necessary. Patients with a history of blood disease and anticoagulant therapy must have blood coagulation function.

7.1.4 Assessment of Anesthesia Risks

Anesthetists should consider whether the patient receives anesthesia in her best physical conditions before surgery, and whether the benefits brought to the patient by this surgery are more than the risks of anesthesia for surgery induced by the coexistent illnesses. Each of the following items may lead to complications during and after surgery and increase the danger of death.

1. Clinical assessment of American society of Anesthesiologists (ASA) is above grade III.
2. Heart failure, digitalis therapy, electrolyte imbalance.
3. Goldman's cardiac risk index is >25.
4. Lung disease and pulmonary abnormalities confirmed by chest X-ray.
5. Renal failure or metabolic acidosis.
6. Abnormal ECG.
7. Acute respiratory tract infection.
8. Severe anemia and hypoproteinemia.
9. Blood diseases related to blood coagulation dysfunction and inevitable anticoagulation therapy.

7.2 Anesthetic Methods and Choices for Hysteroscopy

Although hysteroscopy restricts its stimulation in cervical dilatation and intrauterine operation, since the splanchnic nerves governing the uterus are mainly from the sympathetic nerves of $T_{10–12}$ and $L_{1 \& 2}$ and from the pelvic plexus composed of parasympathetic nerves of $S_{2–4}$, it easily leads to general reactions like reaction of artificial abortion syndrome (RAAS) (that is, bradycardia, arrhythmia, lowered blood pressure, nausea, vomiting, chest tightness, pale, sweating, and so on). Therefore, the anesthetic methods and choices are determined by the following points:

1. Whether diagnostic or therapeutic hysteroscope, flexible or rigid.
2. Non-hospitalized or hospitalized patients.
3. Whether the patients are cooperative mentally and psychologically.
4. The patients' requirements for anesthesia.
5. The surgeons` requirements for anesthesia and proficiency in operation techniques.
6. Duration of operation.

7.2.1 Topical Anesthesia

Topical anesthesia is a kind of anesthetic method by local spray of the anesthetics which has strong penetration and immediate effect into the cervical canal or into the uterine cavity. The commonly used medications are 0.5–1% tetracaine or 2% lidocaine by tamponade with cotton sticks into the cervical canal or by injection into the uterine cavity. Although the topical anesthesia can relieve the pain caused by uterine dilation and systemic adverse reactions, it cannot well relieve the nerve reflex symptoms during intrauterine operation, because it cannot completely block up the nerve reflex of submucosal layer and muscle layer to compression, stretching, and thermal effects of resection or coagulation. However, combined with neuroleptanesthesia, this method can be used for hysteroscopic biopsy and examination, TCRP, and other minitraumatic procedures.

7.2.2 Paracervical Nerve Block

Paracervical nerve block is administered with the cervical injection of 0.5 ml to 1 ml of 2% lidocaine at 4, 8, and 10 o'clock position and 0.5 cm to outer edge of cervix with 3 cm deep of the needle insertion, which can loosen cervical canal in 92% of patients and reduce the incidence of RAAS significantly. Theoretically the paracervical nerve block with high concentration and high volume can be more effective, but there exists injection pain and systemic toxic reactions, and the nerve reflexes of the fundus and the corpus cannot be completely released.

7.2.3 Epidural Anesthesia and Subarachnoid Block

Epidural anesthesia consists of continuous epidural anesthesia and single epidural anesthesia, and is a widely used and skillful anesthetic method. It can modify the duration and the level of anesthesia freely according to the length of operative