Tomoaki Taguchi · Tadashi Iwanaka
Takao Okamatsu *Editors*

Operative General Surgery in Neonates and Infants

Springer

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Preface

I am very happy to publish *Operative General Surgery in Neonates and Infants*, the first book on pediatric surgical procedures in English by young and enthusiastic Japanese pediatric surgeons. The purposes of this book are to introduce current Japanese surgical procedures in pediatric surgery and to provide educational materials for the surgical procedures using simple illustrations and explanatory photographs for new pediatric surgeons. As the graphic illustrations demonstrate operating scenes in great detail, readers can envision the operating field more clearly than they could with photographs alone. Consequently, this book is recommended for new Asian pediatric surgeons and trainees.

One of the motives in editing this book can be explained as follows. It was clear that Cambodia's medical society, which had been entirely devastated by the Khmer Rouge from 1975 to 1980, was in need of help to reorganize with the standards of contemporary associations. Remarkable achievement now has been made by the enthusiastic efforts of Cambodian doctors who survived that dark period, and by foreign initiatives. In order to spread pediatric surgical service to rural areas of Cambodia, the Department of Pediatric Surgery of the National Pediatric Hospital (NPH) started a 1-year training course in pediatric surgery for young postgraduate surgeons in rural hospitals starting in 2006 in collaboration with the University of Health Science and the Foundation for International Development/Relief (FIDR). As this program has been running very effectively, more than 20 authorized pediatric surgeons are working in rural hospitals of Cambodia currently. Still, however, they feel the lack of clinical experience and educational tools.

Contributors to this book are all experts with sufficient experience. I believe the book will be a good tutor in pediatric surgical procedures for those young pediatric surgeons. Here, we have attempted to bring into focus not only current knowledge of pediatric surgical techniques in Japan but pre- and postoperative care of patients, and we have presented this material as guidelines to the staff caring for infants with surgically treatable diseases.

I particularly appreciate Prof. Tomoaki Taguchi, M.D, Ph.D., professor of pediatric surgery and the chief editor of the book, for his strong leadership in arranging the work of editing this volume. This new English publication, *Operative General Surgery in Neonates and Infants*, would not have been realized without his leadership.

Thanks also to the editors and all contributors for their professional advice and contributions, and thanks as well to the Japanese Society of Pediatric Surgeons for their kind support.

I would like to express special gratitude to Mr. Kiyohiko Takayama, Springer Japan, and Ms. Maya Kiyosawa, Medical View Co. (the publisher of the original Japanese book), for their sincere cooperation in publishing this present volume.

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Preface

Operative General Surgery in Neonates and Infants was proposed by Dr. Takao Okamatsu in order to create educational materials for young pediatric surgeons around the world. Actually, we had already published *Standard Pediatric Surgical Procedures* (Medical View Co., edited by Tomoaki Taguchi and Tadashi Iwanaka) in Japanese in 2013, in order to cover all operative procedures of pediatric surgery. Following the proposal by Dr. Okamatsu, we picked up the important basic procedures from this Japanese book and asked the original authors to translate their Japanese to English. Medical View Co. (Ms. Maya Kiyosawa and Mr. Naohiro Asami) kindly permitted us to use the original figures from that book in this new English-language volume.

The present publication introduces the most up-to-date representative Japanese pediatric surgical procedures and points in pre- and postoperative management. Furthermore, *Operative General Surgery in Neonates and Infants* is characterized by the use of many simple illustrations to explain each procedure. We always insist that young trainees themselves draw illustrations in the operational record and encourage them by saying that "Good illustrators can become good surgeons." We are confident that their drawing illustrations by themselves is a gold-standard shortcut to understanding operative anatomy and procedures. Therefore, *Operative General Surgery in Neonates and Infants* will become a standard bible for young trainees around the world, especially in developing countries.

The authors for each procedure are experts in pediatric surgery who are operating almost every day as surgeons-in-chief in university hospitals or children's hospitals. All of them are qualified pediatric surgeons and members of the Japanese Society of Pediatric Surgeons. They are all good clinicians as well as educators. We appreciate their efforts and contributions to *Operative General Surgery in Neonates and Infants*.

Finally, we would like to thank Mr. Kiyohiko Takayama and Ms. Mariko Kubota, Springer Japan, for their wise decisions and kind consideration in publishing this book.

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Kouji Masumoto

Abstract

In the field of pediatric surgery, the central venous catheterization technique is frequently used for the purposes of intensive care, nutrition management, administration of anticancer agents, and so on. Therefore, it is critical for pediatric surgeons to be proficient in the catheterization technique to secure a central venous route. This chapter describes the reality of and necessary precautions in central venous catheterization for children and presents complications that may occur due to catheterization. In this chapter, the first two basic central venous catheter (CVC) insertion techniques are described: the Seldinger technique and the cutdown technique. Then catheterization techniques for long-term catheter placement such as port-type and Broviac/Hickman catheters and CVC insertion techniques for continuous hemodiafiltration (CHDF) are also described.

Keywords

Central venous catheter • Catheterization • Seldinger technique • Cutdown technique • Complications

1.1 CVC Insertion Techniques

Typically external or internal jugular veins are used as a route for CVC insertion, and the veins are basically accessed via a subclavian vein [1–3]. There are two subclavian puncture techniques: the Seldinger technique to insert a catheter by using a guide wire and the direct puncture technique to make a puncture on a subclavian vein by directly using a puncture needle and inserting a catheter from its outer tube. Normally, the Seldinger technique is selected for better safety [4]. These techniques are commonly used for catheterization for long-term placement, e.g., port-type and Broviac/Hickman catheters, and continuous hemodiafiltration catheterization. If a route cannot be secured by these techniques, instead, the cutdown technique is used for insertion.

1.1.1 Seldinger Technique (Figs. 1.1 and 1.2)

1. Before inserting the catheter, check its length with a chest plain film.

2. Place the patient in the Trendelenburg position. Usually, in the past, a pillow was placed beneath the shoulder to hold the chest out. However, the author does not do this because the pillow itself may make the body lean toward either side. If you decide to use a pillow, make sure the pillow is placed at the center of the body with due caution. To make sure the guide wire is inserted into the right atrium when inserting it (as described later), prepare for electrocardiographic monitoring.

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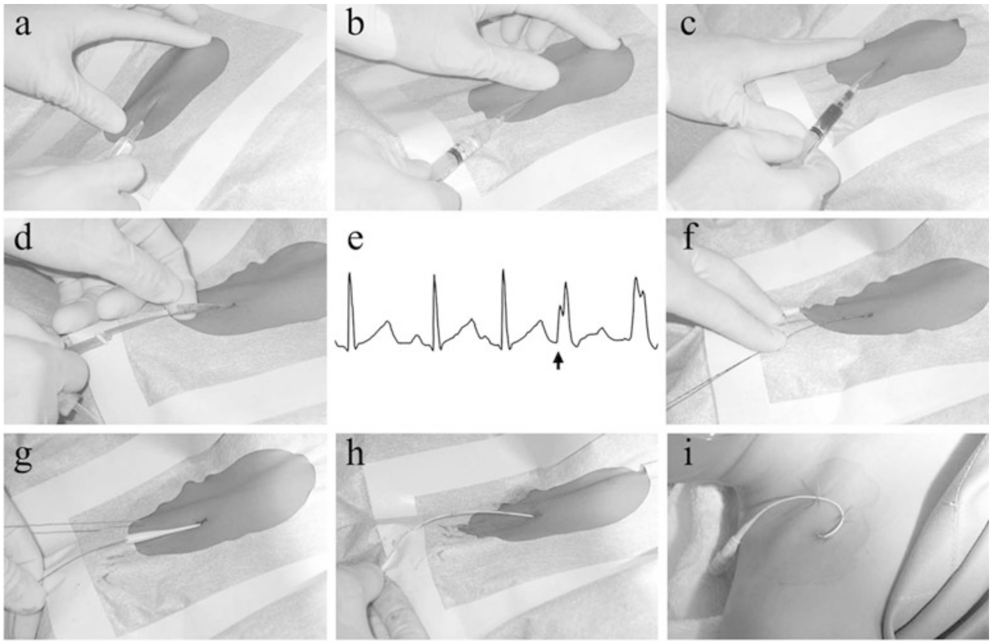

Fig. 1.1 Central venous catheterization by subclavian puncture (Seldinger technique). (**a**) Anesthetizing the right subclavian area. Exploratory puncture will follow. (**b**) Using the supplied sheathed catheter for the puncture. (**c**) Reversed venous blood flow observed with the puncture. (**d**) Inserting the guide wire along the sheath. (**e**) Irregular heartbeats observed on an electrocardiogram during guide wire insertion (*Arrow*). (**f**)The sheath removed and the guide wire drawn back to the point where no irregular heartbeats are observed. (**g**) Inserting the dilator for route dilation. (**h**) Inserting the catheter along the guide wire. (**i**) Fixing the catheter

3. In principle, use advanced barrier precautions; operators should wear a sterile gown, mask, cap, and sterile gloves and sterilize a sufficient area on and around the skin part where the insertion will take place.
4. Use a 2.5-cc syringe of 1 % Xylocaine or procaine hydrochloride with a 25G or 23G needle to locally anesthetize the insertion point and the portion below the skin (Fig. 1.1a).
5. Then, use a 2.5-cc syringe with 23G needle to conduct an exploratory puncture. The puncture site should be the outer third of the clavicle, and the needlepoint should start from the point of 1–2 finger widths toward the tail from the center of the clavicle and go toward the suprasternal area. When the exploratory puncture on the subclavian vein is confirmed as successful, mark the direction in preparation for the puncture. Recently, it has been recommended to check the subclavian vein location under echographic guidance [5].
6. For the puncture, an indwelling needle supplied with a respective catheter is often used (Fig. 1.1b). However, 22G or smaller indwelling needles may not reach the subclavian vein and may be deflected depending on the force of the puncture, which may lead the needlepoint toward the pleural cavity. So, it is better to use an 18G or 20G indwelling needle. If echography is available for this puncture, it will help effectively track the puncture needlepoint and improve the safety.
7. If any reversed vascular flow is observed (Fig. 1.1c), advance the outer tube of the puncture needle further, take out the inner tube, and insert the guide wire (Fig. 1.1d). The guide wire is inserted into the vessel if it can go in smoothly. If any resistance is felt, it may be inserted outside the blood vessels. In this case, be sure to remove the guide wire and check for reversed blood flow from the outer tube of the indwelling needle. If no reversed blood flow is observed, you should redo this puncture procedure.
8. When the guide wire is inserted into the vessel, turn the neck toward the punctured side to prevent the guide wire being inserted into the jugular vein and then further advance the guide wire. When the guide wire enters deep into the vessel, abnormal cardiac rhythm should be observed on an electrocardiogram (Fig. 1.1e). These irregular heartbeats should be caused by stimuli on the right ventricle from guide wire insertion. So at this point, slightly withdraw the guide wire and hold it where no irregular heartbeats are observed (Fig. 1.1f).
9. Cut the puncture site with a sharp-pointed knife and insert a supplied dilator along the guide wire (Fig. 1.1g) to dilate the catheter insertion route.
10. Withdraw the dilator and insert the catheter to the extent determined in advance (Fig. 1.1h).

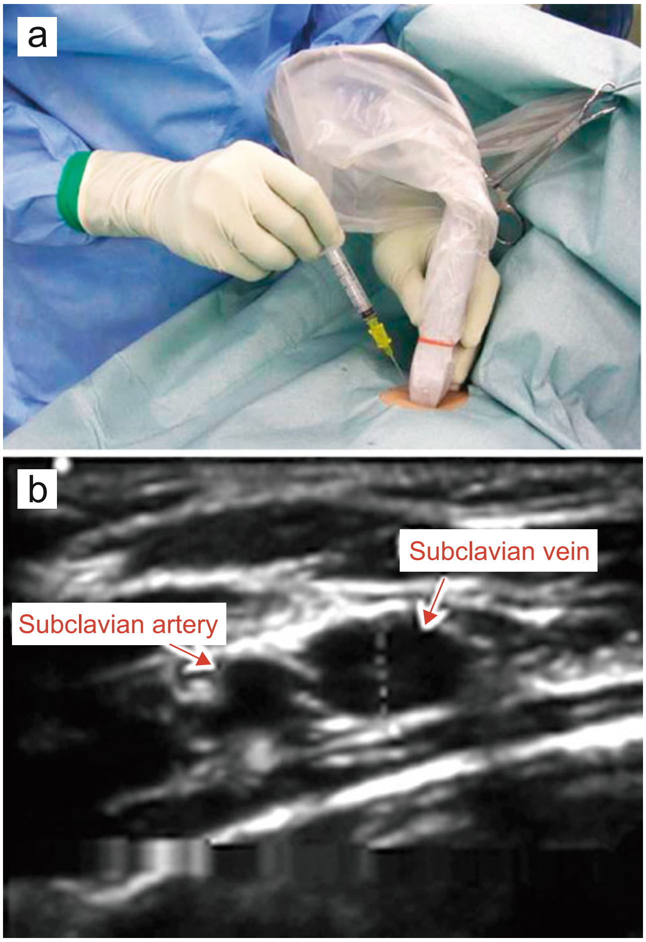

Fig. 1.2 Locating the subclavian vein under echocardiographic guidance. (**a**) Subclavian puncture under echocardiographic guidance. (**b**) Subclavian vessels on echocardiography. When pressed by an echocardiographic probe, the vein is flattened but the lumen of the artery is maintained and beats can be observed

11. Fix the catheter on the skin (Fig. 1.1i). If any fixing device is supplied with the catheter, it is better to use it to minimize the risk of accidents during withdrawal.
12. After catheter insertion, be sure to take a chest plain film and check that the tip of the catheter is in the superior vena cava or the right atrium. Also, check whether any complications (pneumothorax, hemothorax, or breast-wall hematoma) have developed.

1.1.2 Cutdown Technique

For the central venous approach, the cutdown technique is a final procedure for route securement and is used when a puncture is unsuccessful with the Seldinger technique or when risks associated with a puncture technique should be avoided [1–3]. Typically it is used for approaches to internal jugular veins and femoral veins but it is also used for cases where making a puncture on a peripheral vein is difficult or in order to secure an arterial line through the radial artery. In this section, the cutdown procedure on a right internal jugular vein is described.

1. Before inserting the catheter, check its length with a chest plain film.
2. Turn the head of the patient to the left and check the position of the right sternocleidomastoid muscle. To make sure the guide wire is inserted into the right atrium, when inserting it (as described later), prepare for electrocardiographic monitoring.
3. In principle, use advanced barrier precautions; operators should wear a sterile gown, mask, cap, and sterile gloves and sterilize a sufficient area on and around the skin part where the insertion will take place.
4. Use a 2.5-cc syringe of 1 % Xylocaine or procaine hydrochloride with a 25G or 23G needle to locally anesthetize the incised skin site and the portion below the skin.
5. An internal jugular vein forms a sheath together with the common artery at the back of the sternocleidomastoid muscle. For a normal puncture procedure, the vertex of the triangle formed by the sternocleidomastoid muscle attachment sits on the clavicle and the sternal bone, and the clavicle should be the puncture site. However, for children's cutdown procedures, the skin at the point 1–2 cm closer to the head than this triangle should be cut by approximately 2 cm (Fig. 1.3).
6. Use a mosquito pean to dilate the skin and platysma, and the sternocleidomastoid muscle below them will be exposed. Vertically split the sternocleidomastoid muscle and then the internal jugular vein covered with a sheath becomes directly visible (Fig. 1.4).
7. Scoop up the internal jugular vein and appropriately exfoliate the tissue around the vein to allow two silk threads to pass through it. Divide these threads into the central side and peripheral side to grasp and hold the vein. Check that the vessel is dilated when the central side is lifted up while the peripheral side is loosened. However, as veins are prone to constrict due to spasms caused by procedure and stimuli, dilation may not be observed immediately. In such cases, spray 1 % Xylocaine around the vessel and then the internal jugular vein gradually dilates (Fig. 1.5).
8. Pull up the threads and insert the puncture needle supplied with the catheter into the central part of the internal jugular vein. Alternatively, use a sharp-pointed knife to make a small vertical incision and insert the puncture needle from the incision site. When the needle is inserted approximately 1 cm into the vessel, withdraw the puncture needle's inner tube, loosen the silk thread

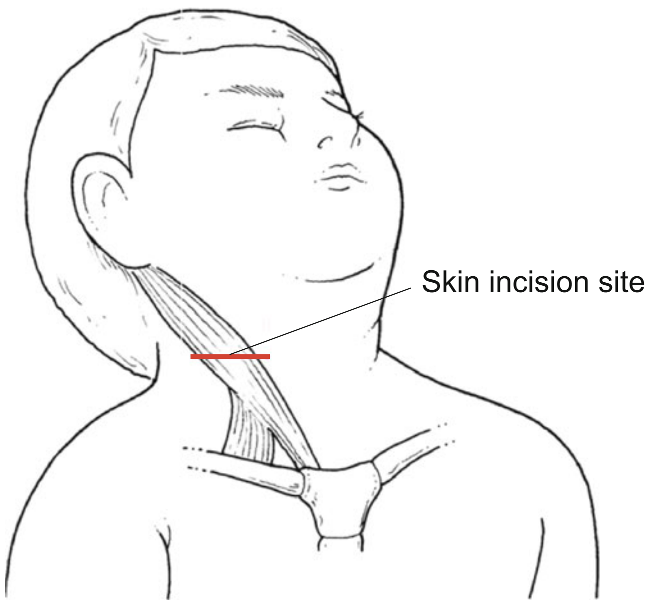

Fig. 1.3 Reference skin incision size for cutdown of the internal jugular vein

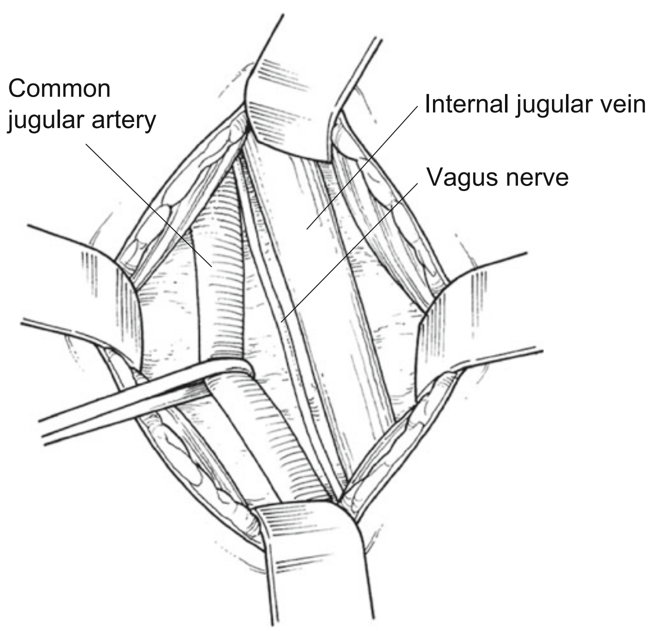

Fig. 1.4 Positional relation of the internal jugular vein and common artery

on the central side, advance the outer tube only, and place the puncture needle's outer tube in the inner jugular vein.

9. Confirm a reversed blood flow through the puncture needle's outer tube and insert the guide wire. When the guide wire enters deep into the vessel, abnormal cardiac rhythm should be observed on an electrocardiogram. At this point, slightly withdraw the guide wire and grasp it at a point where no irregular heartbeats are observed.
10. Insert the supplied dilator along the guide wire to dilate the catheter insertion route. Then withdraw the dilator and insert the catheter along the guide wire to the extent determined in advance.
11. If bleeding from the puncture is low after the catheter insertion, remove the grasping silk threads. In the event that bleeding from the incision is expected, ligate the peripheral side. The central side should also be ligated but to the extent that no catheter obstruction is caused. At this point, ensure that blood can flow into the catheter.
12. After closing the wound and fixing the catheter on the skin, finally, be sure to take a chest plain film and check that the tip of the catheter is in the superior vena cava or the right atrium.

1.2 Insertion of Port-Type Catheter for Long-Term Placement

A port-type catheter consists of a catheter tube that is inserted into a vessel and a reservoir which is embedded under the skin. It is often used for administration of anti-cancer drugs and long-term nutrition management [6]. As there is no risk of spontaneous extraction and no part is exposed except during the administration period, patients may even have a bath; thus QOL is improved. At the same time, however, a skin puncture procedure is necessary for use and repeated puncture procedures may cause the risk of skin necrosis of the site [6]. Basal plane sizes in most port-type catheter reservoirs are about 25–30 mm and the height range is 10–15 mm. Thus, they are typically used for patients in childhood or later. A catheter size appropriate for the body size of each patient should be selected. Typical insertion sites are subclavian and internal jugular veins.

1.2.1 Reality of Port-Type Catheter Insertion Techniques

In practice, two processes are conducted: catheter insertion and reservoir placement [7]. Venous puncture for catheter insertion will not be covered here, because the use of the aforementioned Seldinger technique or cutdown technique is assumed. For insertion of a port-type catheter, fluoroscopy during operation is essential to identify the location of the catheter tip.

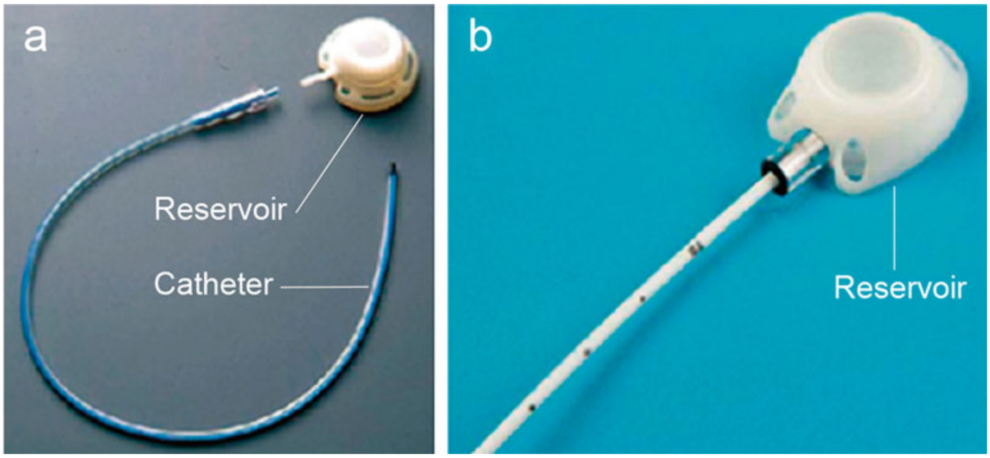

Fig. 1.5 Port-type catheter. Consists of (**a**) a catheter tube to insert into a vessel and (**b**) a reservoir embedded under the skin for infusion from outside through a needle puncture

1.2.2 Procedures of Access of Central Venous Route by Using the Subclavian Vein

1. The procedures are the same as for the Seldinger technique through to Step 8 (guide wire insertion). After the guide wire insertion, make an incision of approximately 1 cm on the skin for easy insertion of the sheath introducer for catheter insertion.

2. Insert the sheath introducer into the vein. The point is the insertion with rotating the sheath introducer equipped with a dilator through the guide wire to dilate the route (Fig. 1.8). At this point, use fluoroscopy during operation to make sure the sheath introducer tip does not advance too deeply.
3. Withdraw the dilator and leave the sheath introducer only. At this point, close off the sheath introducer outlet using one finger to prevent bleeding and air tapping.
4. Insert the catheter through the sheath introducer under the fluoroscopic guidance. Ensure that the catheter tip goes into the superior vena cava with care.
5. Peel away and withdraw the sheath introducer. At this point, it is important to have an assistant hold the catheter to prevent extraction. After withdrawing the sheath introducer, under fluoroscopic guidance, be sure to check that the catheter tip location remains unchanged.
6. Proceed to the reservoir placement process. The placement position should be as flat a plane as possible in the precordial region. It should also have relatively thicker subcutaneous fat while not overlapping with the mammary gland. After selecting an appropriate position, make an incision of approximately 2.5 cm in the skin.
7. From the skin incision opening, create a subcutaneous pocket equivalent to the size of the reservoir. Puncturing by needle is difficult if subcutaneous fat on the reservoir is thick, but if it is too thin, skin necrosis may be caused. Therefore, generally a subcutaneous thickness of 5–20 mm on the reservoir is recommended. Also, the skin incision must not overlap with the placement site of reservoir unit (Fig. 1.6).
8. With the supplied tunneller (see Fig. 1.8), develop a subcutaneous tunnel between the catheter insertion site and the skin incision for reservoir placement (Fig. 1.6).
9. Connect the peripheral side of the catheter with the tunneller, let it through the subcutaneous tunnel and carefully draw it through to the subcutaneous pocket for reservoir placement. At this point also, under fluoroscopic guidance, check that the catheter tip is not dislocated.
10. After checking the appropriate catheter length to remain in the body, cut the catheter to the required length and connect it to the reservoir. Then use the supplied catheter lock to lock the catheter to the reservoir. For this step, care must be exercised not to let the catheter come out.
11. Place the reservoir in the subcutaneous pocket and fix it to the fascia of the pectoral major muscle using two- or three-point suturing.
12. Use the non-corning needle (Huber needle; Fig. 1.7) to puncture the reservoir to check for any obstruction in the lumen.

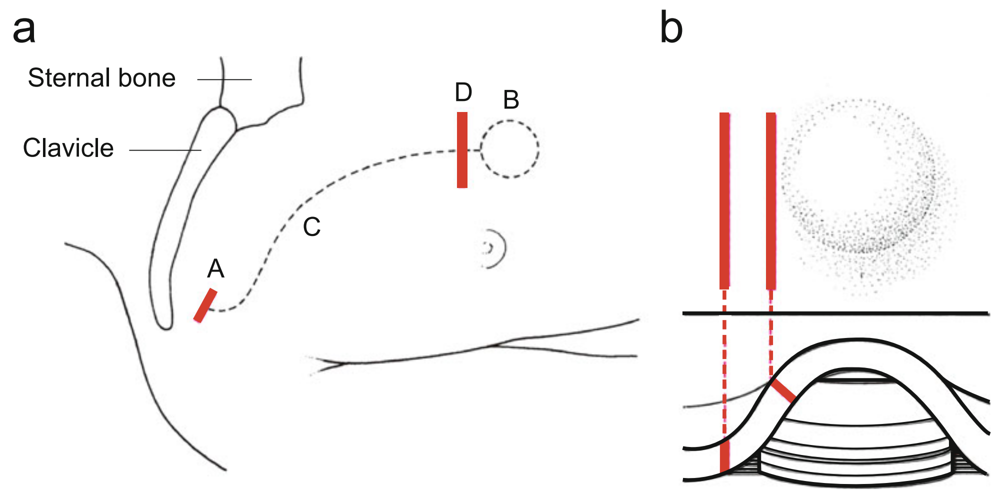

Fig. 1.6 Reservoir placement position. (**a**) Reservoir placement position and subcutaneous tunnel (*A* skin incision for catheter insertion, *B* subcutaneous tunnel for catheter, *C* reservoir placement position, *D* skin incision for reservoir insertion). (**b**) Reservoir placement position and skin incision (suture) site. The solid line represents a skin incision (suture) site. As skin troubles may occur when the skin incision (suture) site is close to the reservoir line as indicated in the left figure, ensure that the skin incision (suture) site does not overlap with the reservoir as indicated in the right figure

Fig. 1.7 Huber needle. The *right* and *left* figures show an example of a Huber needle (Smith Medical's Gripper Needle) and a puncture image of a Huber needle into the reservoir (Toray Medical's Winged Surecan)

13. Close off each skin incision opening to end the procedures. At the end, be sure to take a chest plain film and check for any complications.

1.3 Insertion of Broviac/Hickman Catheter for Long-Term Placement

A Broviac/Hickman catheter has a Dacron cuff on the catheter tube, which is to be buried and subsequently adhere to subcutaneous tissues (Fig. 1.8) [5, 7]. As with port-type catheters, it is often used for the administration of anticancer drugs and long-term nutrition management. It has advantages in that adhesion of the cuff reduces the possibility of accidental withdrawal and localized infection of the catheter insertion site to systemic infection is blocked by the cuff. The minimum diameter of the catheters is 2.7 Fr for a single lumen and 5 Fr for double lumens. It is often used for patients in infants or later and appropriate catheters should be selected according to the body size [8]. Typical insertion sites are subclavian and internal jugular veins.

1.3.1 Reality of Broviac/Hickman Catheter Insertion Techniques

For insertion of a Broviac/Hickman catheter (Fig. 1.8), there are two processes: insertion of the catheter and placement of the Dacron cuff equipped on the catheter. Venous puncture for catheter insertion will not be covered here because the use of the aforementioned Seldinger technique or cutdown technique is assumed. For insertion of a Broviac/Hickman catheter, fluoroscopy during operation is essential to adjust the catheter length and identify the location of the catheter tip.

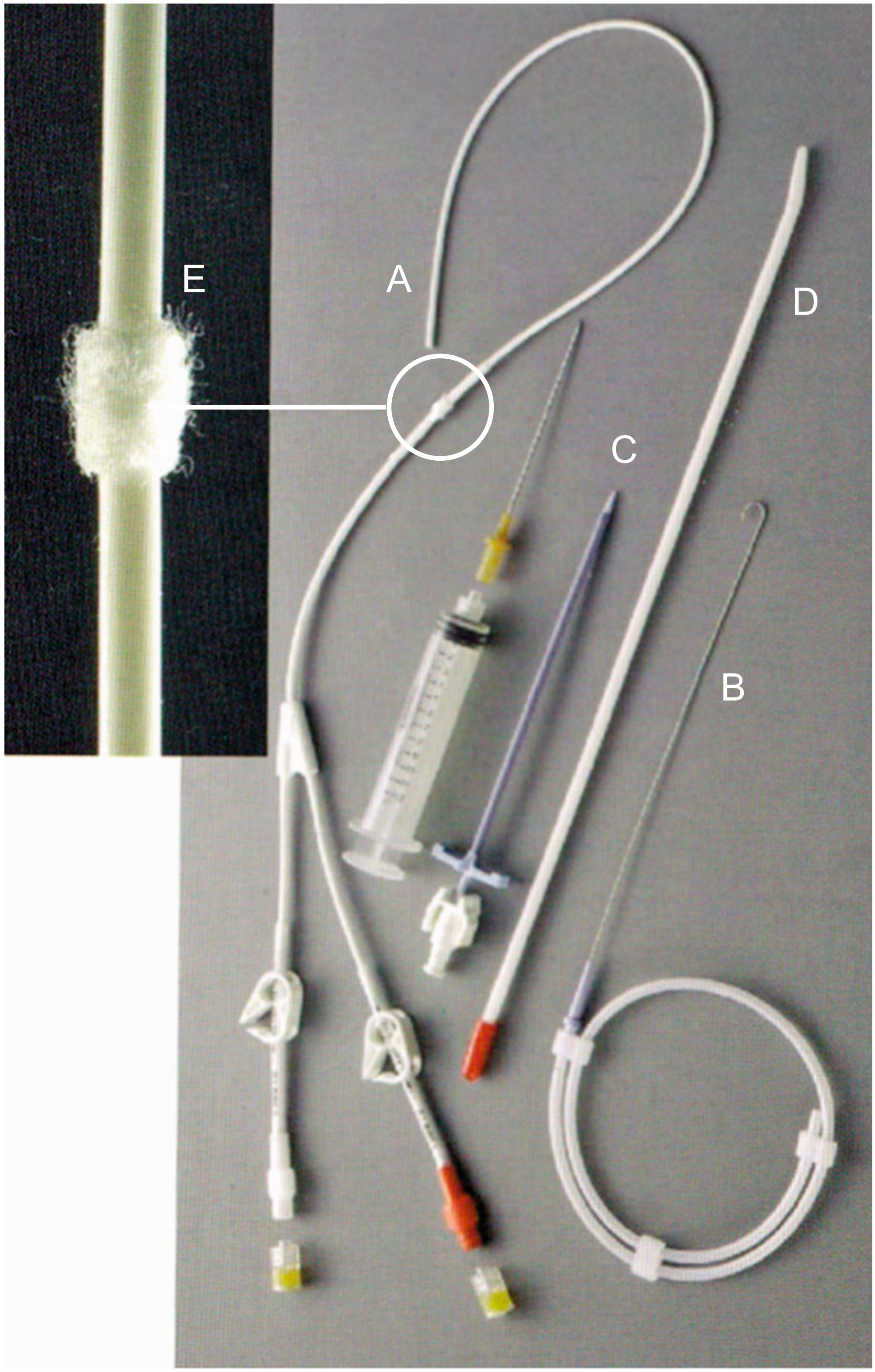

Fig. 1.8 Hickman catheter set. A Broviac/Hickman catheter has a Dacron cuff (E) on the catheter tube to insert into a vessel, which is to be buried and subsequently adhere to hypodermal tissues. (**a**) catheter, (**b**) guide wire, (**c**) sheath introducer with dilator, (**d**) tunneller, (**e**) Dacron cuff

1.3.2 Procedures of Access of Central Venous Route by Using the Subclavian Vein

1. The procedures are the same as for the CVC insertion technique through to the step of guide wire insertion. After the guide wire insertion, use the same procedures for the port-type catheter for insertion of the sheath introducer for catheter insertion (Steps 1–3 of the port-type catheter insertion).

2. Following the insertion of the guide wire, determine a Broviac/Hickman catheter insertion site on the skin and check the Dacron cuff (Fig. 1.8) placement site under the skin. Then, under the fluoroscopic guidance, cut off the tip to adjust its length so that the tip position is in the superior vena cava or right atrium.
3. Make a 7–8 mm skin incision for insertion of the Broviac/Hickman catheter, and use the supplied tunneller to guide this catheter to the insertion port of the sheath introducer. At this point, make sure to set the Dacron cuff placement site sufficiently apart from the skin insertion site.
4. With the dilator extracted, insert the catheter through the sheath introducer under the fluoroscopic guidance. Ensure that the catheter tip goes into the superior vena cava or right atrium with care.
5. Peel away and withdraw the sheath introducer. At this point, it is important to have an assistant hold the catheter to prevent extraction. After withdrawing the sheath introducer, check again, under fluoroscopic guidance, that the catheter tip location remains unchanged.
6. Check the catheter tip position and the cuff position, and close off the wound and fix the catheter to the skin (Fig. 1.9). It takes 2–3 weeks until the cuff is fixed under the skin. Exert care not to let the catheter come out during the period.

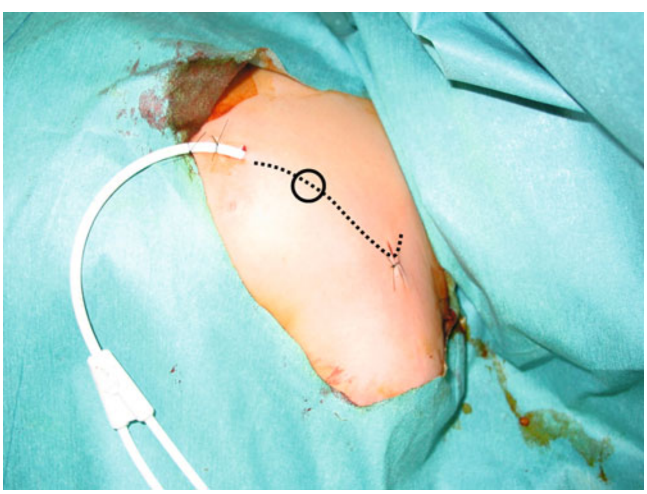

Fig. 1.9 Broviac catheter placement. Place the Dacron cuff under the skin away from the catheter insertion site (the part indicated in the *solid circle*). The *dotted line* indicates the subcutaneous tunnel site of the catheter

1.4 CHDF (Continuous Hemodiafiltration) Catheter Insertion Techniques

In the past, rapid hemodialysis therapies were difficult for many children as only a few kinds of equipment and catheters appropriate for children were available. In recent years, however, development of equipment, modules, and small-diameter catheters (6 Fr/7 Fr) intended for use in children have been advanced, and techniques are becoming available for treating them. For CHDF in rapid hemodialysis therapies, it is important to keep a stable blood flow rate and stabilize the circulation dynamics. In particular, continuous reversed blood flow is an important factor [9]. The radial artery or internal jugular veins/superior vena cava are often used to cause sufficient reversed blood flow, and the recent trend is to use the latter. Options for children include the superior vena cava and subclavian veins, but internal jugular veins are generally regarded as the first choice in consideration of safety in puncture and placement procedures and effectiveness for infection prevention [10].

There are two types of CHDF catheters depending on hole positions: side holes and end holes. Side-hole catheters are generally thin and easy to insert, but have a risk of poor reversed blood flow with a small vascular diameter. End-hole catheters are necessarily larger and usage is relatively limited. For your reference, the corresponding catheter sizes to body weight are indicated in Table 1.1. Notably, the finest-diameter (6 Fr) catheter is most often used for newborns and infants.

The insertion procedures of the CHDF catheters are the same as those of CVC insertion using the Seldinger technique. In recent years, the insertion procedures are often conducted under echocardiographic guidance for the purpose of safety. Thus, the insertion procedures are not covered in this section. However, it is still important to note that the catheter tip must be placed in the superior vena cava or the right atrium in consideration of the reversed blood flow rate.

Table 1.1 The corresponding catheter sizes to body weight

Body weight (kg)	Catheter's size (Fr)	Catheter's length (cm)	Flow (mL/min)
Less than 5	5–7	Less than 10	<15
5–10	7–8	10–13	15–30
10–20	9–11	10–15 (femoral, 20)	30–60
More than 20	11–13	More than 15 (femoral, 20–25)	>60 (3–4 mL/kg)

1.4.1 Complications to Be Specifically Noted for Placement of Central Venous Catheter [11, 12]

1.4.1.1 Pneumothorax

When a puncture needle is inserted too deeply toward the thoracic cavity for subclavian puncture, it breaks the thoracic parietal and visceral pleurae and damages the lung parenchyma, leading to pneumothorax. Although it could be noticed due to suctioning of air from the puncture needle in some cases, it may be left unnoticed until the completion of the insertion procedures in other cases. If coughing is observed after the insertion, pneumothorax is suspected. After catheter insertion, check for coughing, asymmetry in breath sounds on auscultation, and reduction of oxygen saturation by using a pulse oximeter and check with a chest plain film.

1.4.1.2 Hemothorax

Hemothorax occurs when the subclavian artery or vein and thoracic parietal pleura are damaged by the same mechanism as pneumothorax or when the intercostal artery or the lung parenchyma artery is damaged. As with pneumothorax, after catheter insertion, check for asymmetry in breath sounds and reduction of oxygen saturation by using a pulse oximeter and check with a chest plain film.

1.4.1.3 Mislodging/Malposition of Catheter Tip

For prevention of mislodging/malposition, it is important to turn the cervical part toward the puncture side when the tip is inserted into the subclavian vein. In the procedure of subclavian puncture, the catheter tip is often prone to settle in the internal jugular vein, so check the location with a chest plain film after catheter insertion. When malposition into the internal jugular vein is observed, draw the catheter tip back to the innominate vein.

1.4.1.4 Arterial Puncture

The subclavian artery runs along a slightly deeper path in parallel with the subclavian vein; so there is a risk of the arterial puncture when a puncture needle is inserted deeply for subclavian puncture. In the event of arterial puncture, the puncture needle should be withdrawn promptly and sufficient pressure hemostasis should be applied on the site to prevent hematoma formation over 5 min. In such cases, the puncture procedures should be conducted on the opposite side.

1.4.1.5 Injury to the Thoracic Duct

This complication occurs when a merging section of the internal jugular vein and subclavian vein is accidentally damaged at the time of subclavian puncture on the left side. It is associated with no symptoms immediately after the puncture and most often noticed from contamination of the dressing by lymph fluid or accumulated fluid in the left thoracic cavity in a chest plain film.

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Thoracotomy and Laparotomy

2

Noriaki Usui

Abstract

General procedure of thoracotomy and laparotomy is described in this chapter. In terms of thoracotomy, three different types of incision such as posterolateral thoracotomy, axillar vertical incision, and axillar skin crease incision were illustrated. Thoracotomy with conservation of the perithoracic muscles by using axillar skin crease incision was described in detail. The position of patient, selection of intercostal space, and postoperative care tips were also discussed. In respect to laparotomy, various types of approaches such as upper abdominal transverse incision, lower abdominal transverse incision, subcostal incision, Mercedes-Benz incision, pararectal incision, and transumbilical approach were illustrated. Transumbilical approaches including upper half-circumumbilical incision, lower half-circumumbilical skin incision, vertical incision in the umbilicus, and umbilical sliding-window technique were described in detail. Abdominal wound closure and postoperative care tips were also discussed.

Keywords

Thoracotomy • Laparotomy • Axillar skin crease incision • Transumbilical approach

2.1 Thoracotomy

2.1.1 Preoperative Management

A patient is basically in the lateral position under general anesthesia. Although the pulmonary lobe can be easily excluded in neonates and infants, a better operative field can be obtained by degassing the lungs via differential lung ventilation by using a Fogarty catheter as needed in older children. For patients in whom the intraoperative tip position of the endotracheal tube is problematic (e.g., patients with esophageal atresia), the tip position of the endotracheal tube should be confirmed by using a bronchofiberscope before and after postural change.

2.1.2 Operations

2.1.2.1 Position of Patient

After the patient is placed in the lateral position, a pillow of proper height is inserted below the side of the chest to protect the shoulders. Simultaneously, the intercostal space in the affected side should be dilated with slight curvature of the entire chest. The affected arm is elevated by using a handstand or bed cradle to expand to 100–120° (Fig. 2.1). Especially, expanding the arm is necessary for the axillary fold incision. However, caution must be used because an excessively expanded arm may cause brachial plexus palsy. Because infants' bodies are flexible and tend to assume

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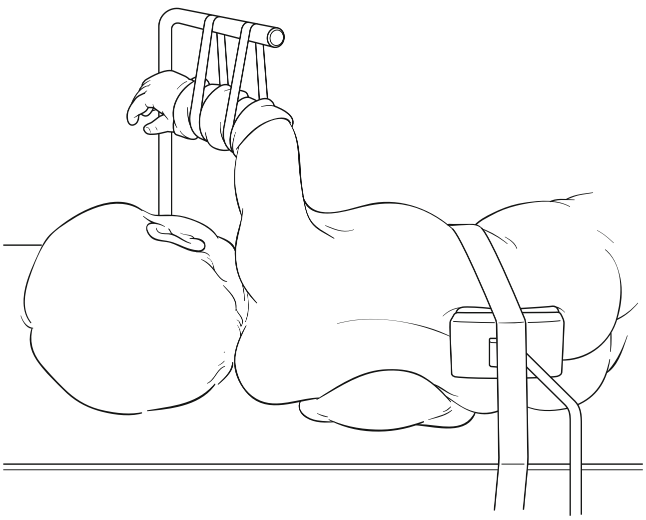

Fig. 2.1 Position of children during thoracotomy

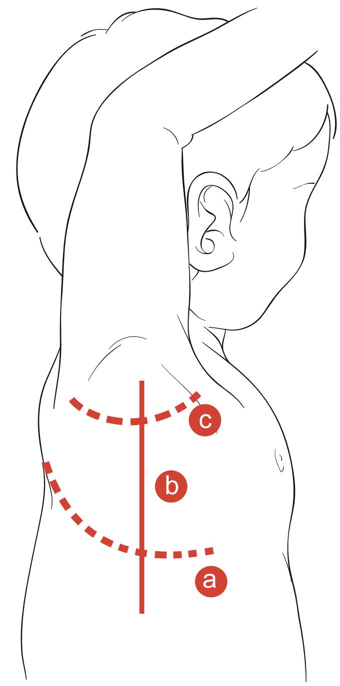

Fig. 2.2 Skin incision line for thoracotomy. (**a**) Posterolateral thoracotomy. (**b**) Axillar vertical incision. (**c**) Axillar skin crease incision

unstable postures, the anterior and posterior hips should be grasped and fixed thoroughly.

2.1.2.2 Selection of Incision

A selection should be made from among the following skin incision approaches: posterolateral thoracotomy, axillar vertical incision, and axillar skin crease incision [1]. Posterolateral thoracotomy (Fig. 2.2a) provides the largest visual field. However, the use of this approach can easily result in subsequent thoracic deformity or elevation of the shoulder because suturing involves a divided part of the muscle, such as the latissimus dorsi muscle, pectoralis major muscle, and sometimes the trapezius muscle (Fig. 2.3). In the axillar vertical incision, a straight skin incision line is made along the middle axillary line (Fig. 2.2b). In the axillar skin crease incision, a loop-shaped skin incision line is made along the skin folds that are located at the most caudal region of the folds existing in the axilla naturally (Fig. 2.2c). After making the skin incision for both the axillar vertical incision and axillar skin crease incision, the dermal flaps should be generated, followed by the performance of thoracotomy by abduction in flexion of the latissimus dorsi muscle and pectoralis major muscle, without dissecting them. The visual field of surgery depends on the size of the window formed by the dermal flaps. However, for the axillar vertical incision, the window can be expanded by extending the skin incision line (Fig. 2.4). Meanwhile, for the axillar skin crease incision, the size of the window is limited. The axillar skin crease incision is the best from a cosmetic viewpoint because the surgical wound will be unified with the folds of the axillary in the long term, with little chance of keloid scar formation (Fig. 2.5). While considering that the visual field is better in the axillar vertical incision, the skin incision approach should be chosen according to the operator's habituation and skill, the degree of adhesion, etc.

Fig. 2.3 Posterolateral thoracotomy: Dissection of the latissimus dorsi muscle and pectoralis major muscle

2.1.2.3 Selection of Intercostal Space

The intercostal space should be chosen according to the targeted site. The standard selections are as follows: the third or fourth intercostal space for patients with esophageal atresia, the fourth or fifth intercostal space for patients who undergo superior lobe resection, the fifth or sixth intercostal space for patients who undergo inferior lobe resection, and the sixth or seventh intercostal space for patients who undergo surgery for the diaphragm or lower esophagus.

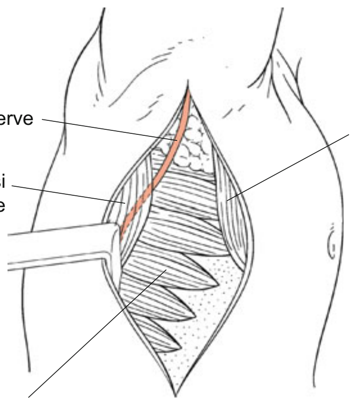

Fig. 2.4 Axillar vertical incision: Exposure of the serratus anterior muscle

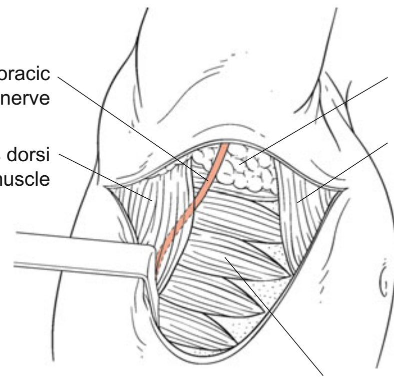

Fig. 2.6 Axillar skin crease incision. Displacement of the latissimus dorsi muscle posteriorly

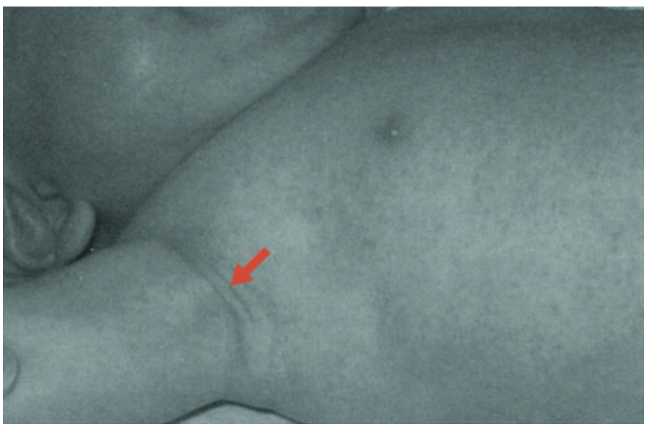

Fig. 2.5 Postoperative wound from the axillar skin crease incision for esophageal atresia (at sixth month after surgery). The skin incised wound (*arrow*) can barely be distinguished from the folds of the axillary

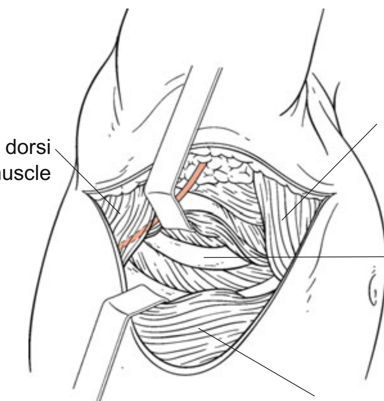

Fig. 2.7 Axillar skin crease incision. Abduction in flexion of the serratus anterior muscle

2.1.2.4 Thoracotomy with Conservation of the Perithoracic Muscles

Regardless of the skin incision approach, it is important to perform thoracotomy while conserving the muscles forming the surroundings of the thorax, such as the latissimus dorsi muscle, pectoralis major muscle, and serratus anterior muscle, as much as possible. This helps to prevent the postoperative limitations of movement and pain and the occurrence of thoracic deformity and elevation of the shoulder during the convalescent phase.

The following section describes thoracotomy with conservation of the perithoracic muscles by using axillar skin crease incision [1] as an example:

Choose the skin incision line located at the most caudal region of the folds. If it is within the area of folds, it can deviate from the axilla to some extent.

Make an incision in the subcutaneous tissues slightly toward the caudal region, and displace the adipose tissues toward the cephalad portion while being careful not to cut the inside of the adipose tissues of the axilla.

To form the dermal flaps, adequately remove the subcutaneous tissues in the layer of the anterior surface of the fascia. Since the skin of neonates and infants is sufficiently extensible, secure the window of the dermal flaps widely.

In the dorsum, incise the fascia along the anterior border of the latissimus dorsi muscle, which traverses and displaces the latissimus dorsi muscle with the long thoracic nerve posteriorly (Fig. 2.6).

In the ventral aspect, perform blunt removal of the pectoralis major muscle until clavicle can be palpated by the finger, and displace the pectoralis major muscle anteriorly.

Identify the intercostal space where thoracotomy is planned, and perform abduction in flexion of the serratus anterior muscle so that the chest wall is exposed on the targeted intercostal space. Remove a part of the serratus anterior muscle because it attaches to the ribs in the ventral aspect, and expose the entire intercostal space where thoracotomy is planned (Fig. 2.7).

Separate the intercostal muscle by using electrocautery while collecting it little by little. In normal thoracotomy, only the pleura are incised. In the extrapleural approach, enter the extrapleural space from outside of the pleura.

2.1.2.5 Exposure of Operation Field and Protection of Wound Border

A rib retractor should be used in the intercostal space in order to expand the operative field by dilating the intercostal spaces. In axillar vertical incision and axillar skin crease incision, to dilate the window of the dermal flap, a retractor should be used at right angles to the rib retractor. Caution must be used to avoid crushing the border of the wound when it is excessively dilated. A wound protector can be used to protect the wound border.

2.1.2.6 Wound Closure

For the closure of the chest wound, care must be taken not to close the intercostal space excessively. Regardless of the dissected length of the intercostal space, three to four stitches for the ribs with absorption threads are adequate for closing the space without causing narrowing of the original intercostal space. When the intercostal space is closed excessively, rib fusion may occur, leading to deformation of the thorax. A drain should be inserted into the thoracic cavity as needed. When the subcutaneous tissues are widely removed, a drain can be placed subcutaneously for the short term.

2.1.3 Postoperative Care Tips

After surgery for treatment of pulmonary hilar lesion and the mediastinum, the postoperative course should be followed by obtaining chest X-rays while carefully monitoring for the onset of chylothorax and complications due to phrenic nerve paralysis.

2.2 Laparotomy

2.2.1 Preoperative Management

A patient is basically in the supine position under general anesthesia. For a patient in whom the operative field is located at the retroperitoneum or at a deep site, a pillow of proper height should be inserted below the back, and the abdomen should be elevated with curvature of the vertebral body according to the targeted site.

2.2.2 Operations

2.2.2.1 Selection from Among the Laparotomy Approaches

The procedures of laparotomy consist of skin incision, subcutaneous tissue incision, fasciotomy, isolation of the muscle or abduction in flexion, and peritoneum incision. Various approaches can be used, depending on the extent of the surgical field. Generally, in children, a transverse incision made across the cleavage lines is preferable to a vertical incision. Various approaches are described in the following section.

2.2.2.2 Upper Abdominal Transverse Incision

This incision is a basic approach for abdominal surgery in children (Fig. 2.8a). This approach allows for a large visual field, and the surgical wound is inconspicuous because the incision is made across the cleavage lines. It crosses the rectus abdominis muscle or the round ligament of the liver. In neonates, ensure that ligation of the round ligament of the

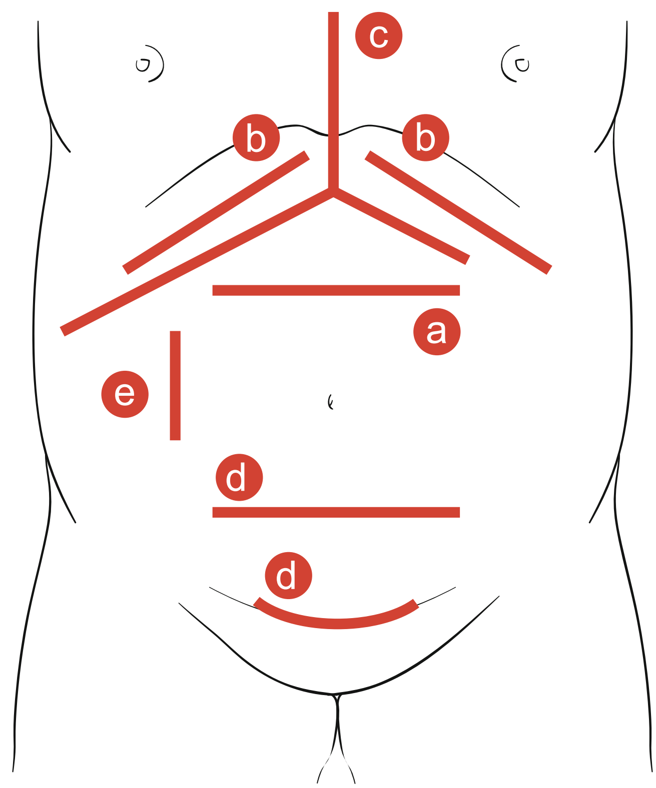

Fig. 2.8 Various approaches for laparotomy. (**a**) Upper abdominal transverse incision. (**b**) Subcostal incision. (**c**) Mercedes-Benz incision. (**d**) Lower abdominal transverse incision (**e**) Pararectal incision

liver is definitely performed because bleeding may occur. This approach is appropriate for gastrointestinal perforation in which the location of perforation cannot be identified.

Make a skin incision along the horizontal line passing through the midpoint between the xiphoid process and the umbilicus.

The length of the skin incision is based on the circumference of both rectus abdominis muscles, and the left and right lengths are adjusted according to the targeted site (Fig. 2.9).

After dilating the subcutaneous tissues, incise the anterior sheath of the rectus abdominis muscle by using electrocautery.

Hold and incise the peritoneum in order to avoid causing damage to the abdominal organs, and subsequently perform the operation.

2.2.2.3 Subcostal Incision

This approach is used for surgery in the hepatobiliary system and the right diaphragm on the right side and for the left diaphragm and the gastric cardia on the left side (Fig. 2.8b). In small infants whose costal arch is almost horizontal and whose skin is sufficiently extensible, the transverse incision along the cleavage is made only on the skin, and the subcutaneous tissues can be removed at the anterior surface of the fascia to incise the fascia and muscle under the costal arch.

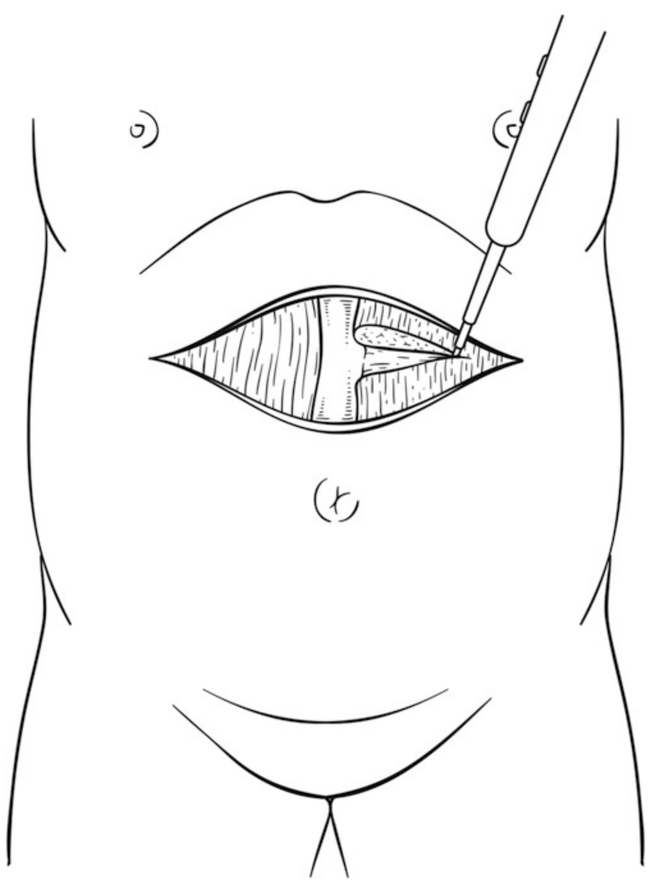

Fig. 2.9 Upper abdominal transverse incision

2.2.2.4 Mercedes-Benz Incision

This is a laparotomy approach in which the bilateral subcostal incisions are connected at the center, and a median incision is made in the cephalad portion. It is used for liver transplantation in older children (Fig. 2.8c).

2.2.2.5 Lower Abdominal Transverse Incision

This approach is used for surgery of the ileocecum, the colon and rectum extending from the sigmoid colon, the genitourinary system, and the pelvic structures (Fig. 2.8d). In a type of surgical incision known as the Pfannenstiel incision, only the line of the skin incision is made caudally, and a loop-shaped incision is made on the folds so that the scar will be hidden by the pubic hair; for the fasciae and muscle, a transverse incision is made on the center of the lower abdominal region.

2.2.2.6 Pararectal Incision

This approach is used for cholecystectomy and appendectomy, although it is currently not used frequently because laparoscopic surgery has been developed (Fig. 2.8e).

2.2.2.7 Transumbilical Approach

Since the umbilicus has been defined as an insertion site for a laparoscopic port, abdominal surgery that utilizes the umbilical region is performed with the purpose of making a surgical wound smaller and less noticeable from a cosmetic viewpoint.

- **Upper half-circumumbilical incision**: a skin incision is made on the cranial semicircle of the folds at, or slightly inside of, the umbilical ring, and the subcutaneous tissues are removed to expose the white line and anterior sheath of the rectus abdominis muscle; subsequently, laparotomy is performed with a median incision (Fig. 2.10a). A transverse incision is also made on the rectus abdominis muscle, if necessary. This approach is used for hypertrophic pyloric stenosis, duodenal atresia, and intestinal atresia. When the window of the skin secured with a wound retractor is too small, dilate it by adding a horizontal supportive incision to the skin (omega-shaped [Ω] incision).
- **Lower half-circumumbilical skin incision**: incise the caudad semicircle of the folds of the umbilical ring, and similarly perform an operation at the lower abdomen (Fig. 2.10b). This approach is used for ovarian cyst and Meckel's diverticulum.
- **Vertical incision in the umbilicus**: since surplus skin is folded in the camerostome of the center of the umbilical region, when retracting and exposing the bottom of the umbilicus to make an incision, a long incision line can be secured sufficiently only in the umbilical ring (Fig. 2.10c). This approach can be applied when performing surgeries for appendicitis, Meckel's

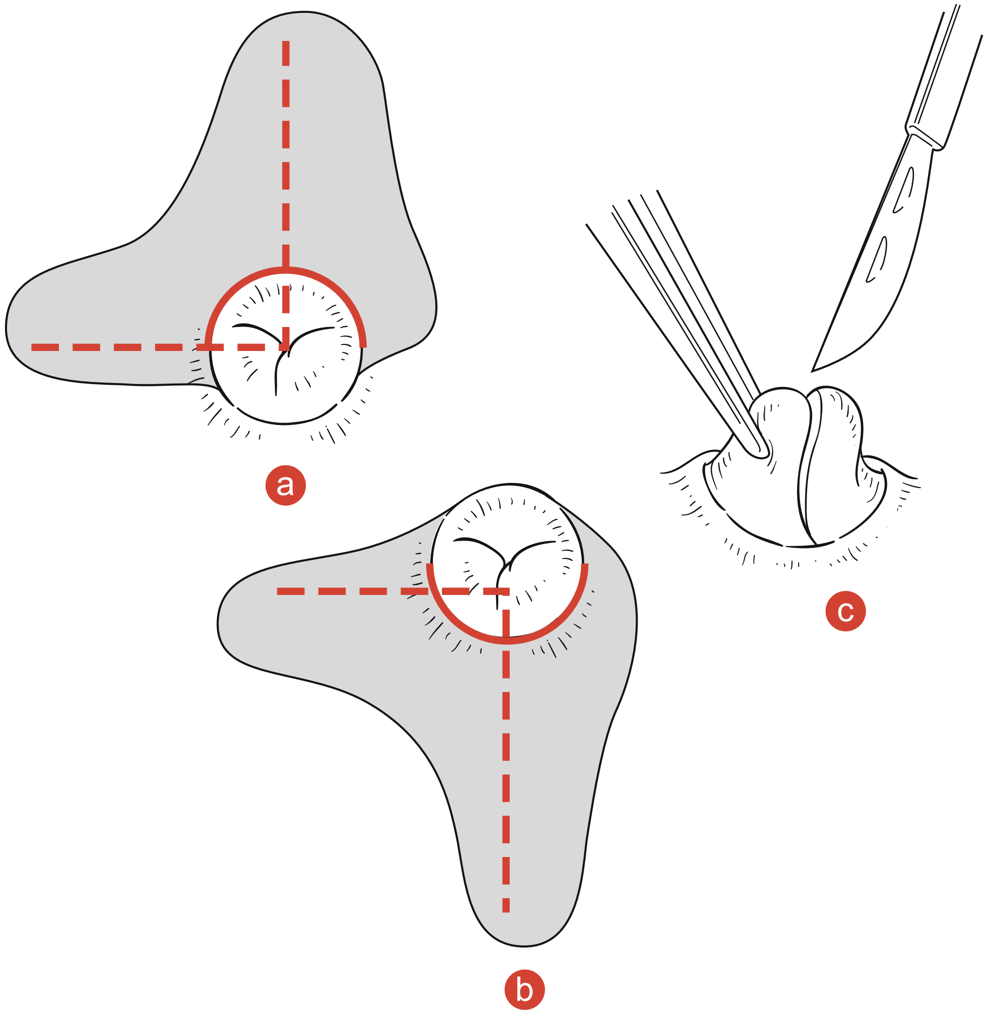

Fig. 2.10 Skin incision for the transumbilical approach. The *oblique line* indicates the range of removal of the subcutaneous tissues. The *dotted line* indicates the incision line of the fascia. (**a**) *Upper half*-circumumbilical incision. (**b**) *Lower half*-circumumbilical skin incision. (**c**) *Vertical* incision in the umbilicus

diverticulum, ovarian cyst, etc., by displacing the targeted organ outside the wound from the window by using a scope with forceps.

- **Umbilical sliding-window technique** [2]: make a circumferential skin incision along (or slightly inside) the umbilical ring, and widely remove the subcutaneous tissues in the anterior surface of the fasciae while leaving the skin of the umbilical region on the abdominal wall (Fig. 2.11a). Then, move the window formed by the dermal flap horizontally to the incised part of the muscle (Fig. 2.11b: sliding). For hypodermatomy of the umbilical region, leave the subcutaneous fat around the skin in the umbilical region and maintain blood flow of the skin. In addition, the skin window can easily be moved horizontally by removing the subcutaneous tissues thoroughly from the incised fascia as well as the contralateral navel. This technique can be applied at various sites, including the upper and lower abdomen, because the operation is performed right over the targeted organ. By expanding the range of removal of the subcutaneous tissues, laparotomy can be performed in the region away from the navel. By expanding the window with supportive incision of the skin, this technique can be applied to surgery for the biliary system and diaphragm.

2.2.2.8 Exposure of Operation Field and Protection of Wound Border

Operations, including the transumbilical approach, have recently tended to be performed with smaller skin incision wounds. A wound protector helps to secure the visual field of the surgery and to protect the wound border (Fig. 2.12).

2.2.2.9 Wound Closure

The closed abdomen procedures include suturation of the peritoneum and the transversalis fascia, suturation of the anterior layer of rectus sheath, and suturation of the subcutaneous tissues and the skin. Dehiscence of the fascia may cause abdominal incisional hernia and scarring in the wounded area. Therefore, double-layer suture is desirable for the peritoneum, muscular layer, and subcutaneous tissues

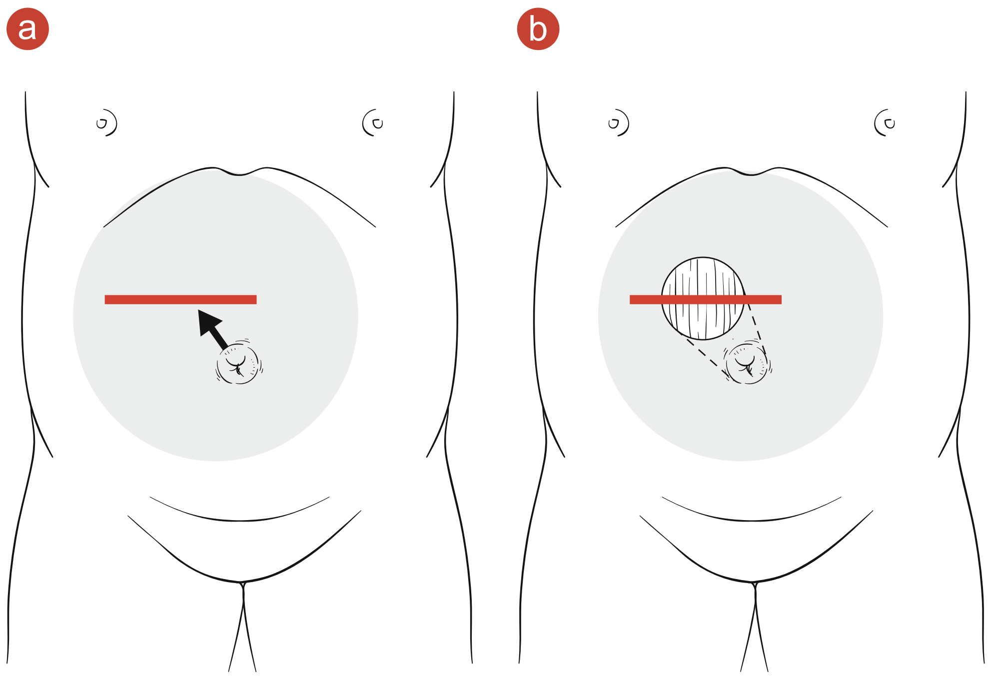

Fig. 2.11 Umbilical sliding-window technique. (**a**) Widely remove the subcutaneous tissues from the region around the incised muscle to the contralateral navel (*shadow area*). (**b**) Move the skin window horizontally to the incised part of the fascia

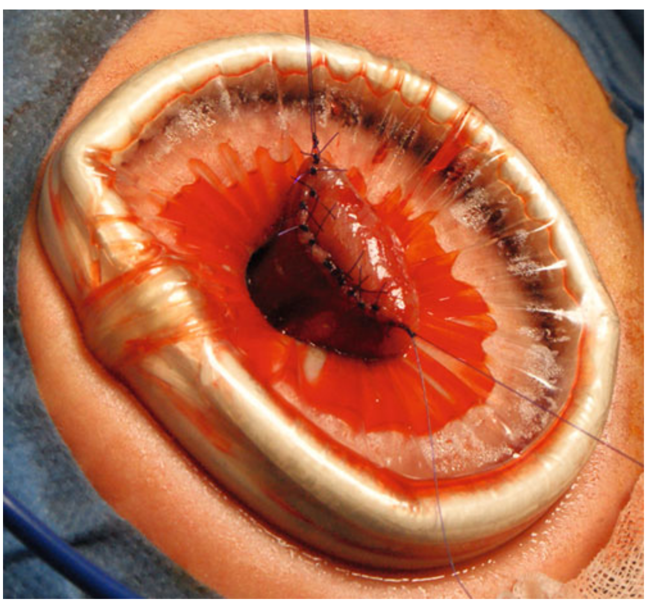

Fig. 2.12 Exposure of operation field and protection of wound border by a wound protector. Duodenoduodenostomy by using umbilical sliding-window technique with a wound protector

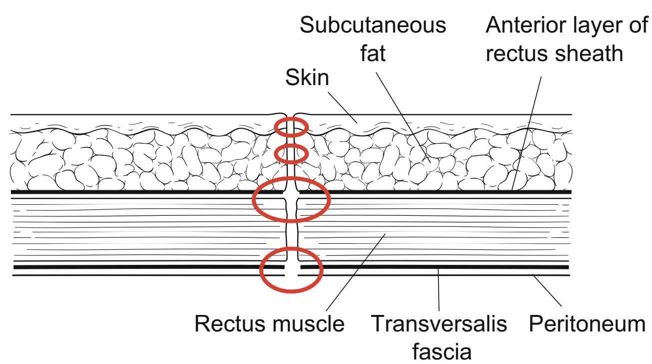

Fig. 2.13 Layer-to-layer suture for abdominal wound closure. Using absorption threads, suture the peritoneum, transversalis fascia, anterior layer of rectus sheath, subcutaneous tissues, and skin by each layer

to layers (Fig. 2.13). For patients in whom re-laparotomy is expected at a higher rate (e.g., patients with biliary atresia), absorbable adhesion barrier materials for preventing adhesion should be used before closing the abdomen.

2.2.3 Postoperative Care Tips

Currently, with the exception of peritonitis associated with intestinal perforation, the abdominal cavity drain is rarely used. When the subcutaneous tissues are widely removed by using the umbilical sliding-window technique, subcutaneous emphysema or redness may occur postoperatively. If this is troublesome for the patient, a thin subcutaneous drain should be placed with slight compression of the skin.

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Laparoscopy and Thoracoscopy

3

Tetsuya Ishimaru and Tadashi Iwanaka

Abstract

Endoscopic surgery, including laparoscopic and thoracoscopic surgery, in children has become widespread in the past few decades due to its minimal invasiveness and better cosmetic results. However, it requires specific expertise and skills that are different from conventional open procedures. Surgeons have to fully understand the basics of endoscopic surgery, such as the lack of three-dimensional information, faint tactile sensation, and restricted movement of surgical devices; in such cases, numerous physiological pneumoperitoneum/pneumothorax effects appear in the patient. In addition, surgeons are required to be proficient in the endoscopic surgical skills acquired through extensive training using box trainers, virtual reality simulators, or animal surgery prior to clinical cases. With regard to pediatric endoscopic surgery, the organs of children are more fragile and the working space is smaller than in adult endoscopic surgery. Therefore, smaller devices and special considerations are needed when performing such procedures in children, particularly among neonates and infants. Moreover, collaboration with a pediatric anesthesiologist is vital for safe and secure procedures.

Keywords

Laparoscopy • Thoracoscopy • Children

3.1 Introduction

Endoscopic surgery offers several advantages, primarily due to its minimal invasiveness, that prevail over its various disadvantages such as

(1) the lack of information on the depth of the operative field, wherein surgeons need to perform procedures assisted by a two-dimensional video monitor;
(2) the limitation in the devices available for endoscopic surgery that can be placed through a thin trocar;
(3) the lack of haptic information;
(4) the difficulty in capturing the entire operative field visually using a camera;
(5) the need to consider the patient's position to obtain an adequate working space; and
(6) the physiological effects of pneumoperitoneum or pneumothorax with carbon dioxide on the patient's condition.

Although the minimal invasiveness and better cosmetic appearance associated with such procedures are promising for pediatric patients, there are challenges and difficulties specific to pediatric surgery, including the presence of

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Table 3.1 Pediatric laparoscopic surgery: indications and procedures

Pyloromyotomy for hypertrophic pyloric stenosis
Fundoplication for gastroesophageal reflux disease
Ladd procedure for malrotation
Small bowel resection for Meckel's diverticulum or enteric duplication
Appendectomy for acute appendicitis
Endorectal pull-through for Hirschsprung's disease
Anorectoplasty for high (intermediate) type of imperforate anus
Portoenterostomy for biliary atresia
Hepaticojejunostomy for congenital biliary dilatation
Splenectomy for some hematological diseases
Catheter insertion (ventriculoperitoneal shunt, peritoneal dialysis catheter, etc.)
Biopsy or excision of abdominal tumor
Repair of congenital diaphragm hernia
Repair of inguinal hernia
Pyeloplasty in hydronephrosis
Nephrectomy for dysplastic kidney
Enucleation for ovarian disease

various diseases and a paucity of cases that necessitates a longer time for standardizing procedures and acquiring excellent surgical skills. Laparoscopic surgery is applied to different diseases in pediatric surgery, as shown in Table 3.1, and its indications are increasing. In this chapter, the basic principles of pediatric laparoscopic and thoracoscopic surgery have been described.

3.2 Laparoscopy

3.2.1 Preoperative Management

No specific preoperative preparation is needed for pediatric endoscopic surgery, but bowel preparation to obtain an adequate working space is desirable. In general, the combination of overnight fasting and an enema prior to surgery is sufficient. However, in some cases with aerophagia, which is frequently associated with neurologically impaired children, a preoperative intermittent aspiration of the stomach through a nasogastric tube is useful to decompress the bowels, especially the transverse colon, because the dilatation of the bowels often interferes with the operative view. In elective cases, the umbilicus is cleaned using olive oil on the day before the planned procedure. In emergency cases involving abdominal pain, such as acute appendicitis, umbilical cleansing is performed after the induction of general anesthesia. Shaving is rarely needed.

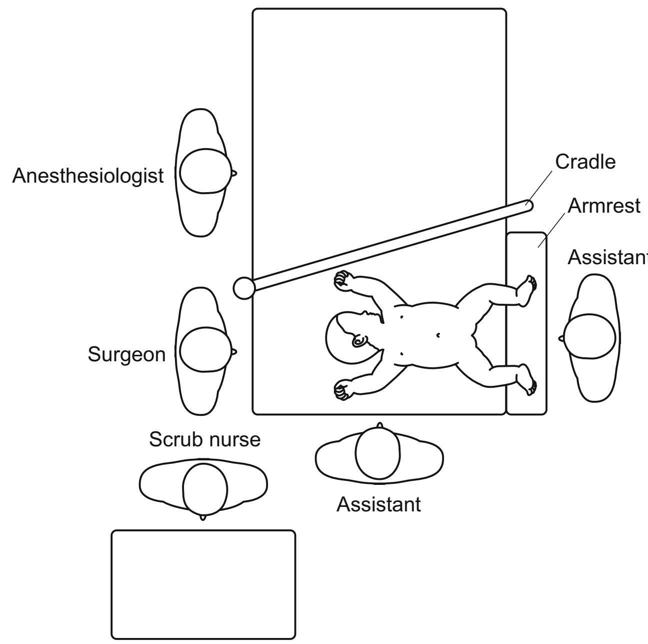

Fig. 3.1 Patient's position for pelvic surgery in infants. In pelvic surgery in infants, it may be helpful to place the patient transversely at the bottom of the bed. An armrest is useful for positioning a taller infant

3.2.2 Patient's Position

Obtaining an adequate working space is critical in pediatric endoscopic surgery. The efficient use of gravity to keep untargeted organs out of view is one of the key factors for successfully completing the procedure. Therefore, the patient's position is fundamental. For upper abdominal procedures, the patient is placed in the reverse Trendelenburg position after inserting trocars. On the other hand, for pelvic procedures, the Trendelenburg position is sufficient to achieve a sufficient working space. For splenectomy or some retroperitoneal tumor resections, the semilateral position is helpful to remove the bowels from the operative field during the procedure. Therefore, it is recommended that the patient should be placed in a semilateral position for the ease of dissection and then moved to the supine position by rotating the bed at the beginning and the end of the procedure for inserting and removing trocars. In pelvic surgery in infants, such as endorectal pull-through for Hirschsprung's disease or anorectoplasty for high-type imperforated anus, it might be helpful to position the patient transversely at the bottom of the bed (Fig. 3.1).

3.2.3 Basic Principles

3.2.3.1 Arrangement of the Operative Theater and Port Placement

The principles of port arrangement for children are identical to those for adults, and a baseball diamond is often used as an analogy (Fig. 3.2). The surgeon stands at the home plate; the surgeon's working ports for his right and left hands are placed at the first and the third bases, respectively; the target lesion is located at the second base; and a scope is inserted from the pitcher's mound. The video monitor is set at the center field; the surgeon and the assistant handling the scope during the procedure should share the same monitor.

3.2.3.2 Pneumoperitoneum

Pneumoperitoneum with carbon dioxide is used in children as well as in adults to achieve sufficient working space. However, the intra-abdominal pressure for children, especially neonates or infants, should be set at a lower level, as its effects on the circulatory system could be more serious, as compared to that of adults. The ideal pneumoperitoneum pressures for children classified by their weight are listed in Table 3.2, and it is preferable to set the pressure to the lowest possible value so as to not interfere with the operative field.

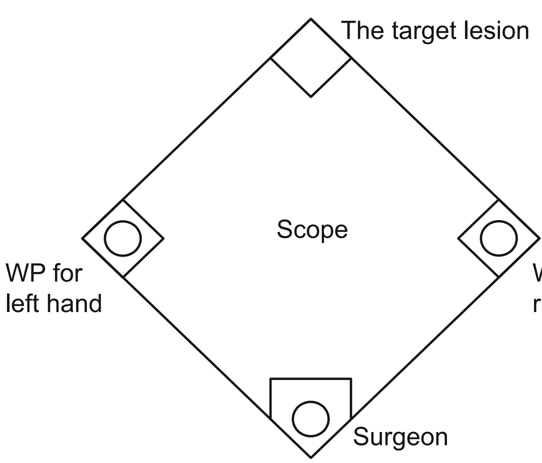

Fig. 3.2 Basic port arrangement. Based on the baseball diamond configuration, a surgeon stands at home plate; the surgeon's working ports (WP) for the right and left hands are placed at the first and the third bases, respectively; the target lesion is located at the second base; and a scope is inserted from the pitcher's mound. Additional ports for retracting or grasping organs are placed depending on the situation

Table 3.2 Ideal pneumoperitoneum pressure

Body weight (kg)	2	5	10	15	20	30
Pneumoperitoneum pressure (mmHg)	5	5	7	8	10	12

3.2.3.3 Collision of Instruments

Pediatric endoscopic surgeons sometimes encounter collisions of the instruments, which can occur both inside and outside the body, making the procedure particularly difficult. Surgeons are sometimes forced to convert to open surgery due to the difficulty in continuing the procedure when severe collision occurs. A flexible scope, with a tip that can be bent, is useful in adult endoscopic surgery, wherein there is sufficient space inside the body; however, its curvature radius is too large to be used inside the smaller body of a neonate or infant, and the oversized tip causes frequent collision with other instruments. A 30° telescope is desirable to avoid collision in children.

Collision is less likely to occur when a fewer number of trocars are used. Therefore, effectively using the patient's position and taking advantage of gravity are vital because these measures can reduce the number of trocars required. Careful selection of the extracorporeal length of trocars is also important for avoiding collision outside the body, and the usage of various lengths of trocars is beneficial in some cases.

3.2.3.4 Considerations of Anesthesia for Pediatric Laparoscopy

The rule a "child is not a miniature form of an adult" applies to anesthesiology, and special considerations are required when performing pediatric anesthesia. The differences between adults and children are greater in endoscopic surgery than in conventional open surgery, and most of these differences are associated with the use of pneumoperitoneum or pneumothorax with carbon dioxide. The elevation of the diaphragm by pneumoperitoneum or collapse of the lung by pneumothorax results in a decrease in the functional residual capacity of the lungs and causes atelectasis. Moreover, increased intra-abdominal or intrathoracic pressure decreases the venous return and leads to reduced cardiac output and low blood pressure. Carbon dioxide absorbed from the peritoneum or pleura causes hypercapnia and careful respiratory management, i.e., a hyperventilation setting, using an end-tidal carbon dioxide monitor, is mandatory. Unilateral intubation may occur due to elevation of the diaphragm after pneumoperitoneum is established, when the tip of an endotracheal tube is placed near the bifurcation. Furthermore, rapid insufflation of a large amount of carbon dioxide can result in hypothermia, and thus, prevention of gas leakage from the port site and efforts to decrease the intraoperative bleeding to avoid frequent suctions are necessary. Warming of the gas is also needed (Fig. 3.3).

3.2.3.5 Suturing and Knot Tying

Techniques of suturing and knot tying in endoscopic surgery are quite different from those used in conventional open surgery. Knot tying can be performed either intracorporeally or extracorporeally depending on the situation. Intracorporeal

Fig. 3.3 Insufflation gas warming system. An infusion extension tube is attached to the tip of the warming tube as the tube is heavy. The insufflation gas warming system by Olympus Medical Systems Corp. is shown. Left warmer (*upper left*). Right tube for warmer

knot tying is performed using instruments with both hands inside the body, such as the use of a needle holder in the right hand and forceps in the left hand. Extracorporeal knot tying is performed using a knot pusher, which is used to push down a knot to the target tissue after tying it manually outside the body (Fig. 3.4). Even a meticulous anastomosis such as the repair of esophageal atresia can be performed using the extracorporeal knot-tying technique by skilled surgeons. In contrast, intracorporeal knot tying is not preferable in small children due to the difficulty of its execution in a small working space.

Some stapling devices are often used in endoscopic surgery not only for bowel cutting or anastomosis but also for dividing the hilar area of the lung or spleen and excision of the bronchus. However, the shaft of these devices is 10 mm in diameter and the length of the blade is over 30 mm; therefore, these devices are sometimes too large to be used in children. The development of instruments appropriate for use in small children is expected.

3.2.4 Instruments for Pediatric Endoscopic Surgery

The typical instruments available for pediatric endoscopic surgery are shown in Fig. 3.5. The length of the instruments is shorter than those used in adult endoscopic surgery, and various types of forceps are commercially available. Instruments, which have a shaft of 3 mm in diameter and approximately 20 cm in length, are usually used for procedures in neonates and small infants. In particular, instruments measuring 5 mm in diameter and 30 cm in length are used for procedures in toddlers. Surgeons can choose the appropriate forceps from various types, including one with fine tip for a more meticulous procedure or one with an atraumatic dull tip, depending on the situation.

Three-mm trocars are often used for surgery in neonates and infants; however, in a procedure requiring suturing, 4-mm trocars are used to insert a needle through the trocar. A 5-mm trocar is needed in procedures where an energy device such as laparoscopic coagulation scissors (LCS) or an ultrasonically activated device (USAD) is used. In children, the abdominal wall is thinner than in adults and the trocar should be fixed to the skin by suturing (Fig. 3.6).

Small wounds are distinctive characteristics of endoscopic surgery. The elongation of the wound to manipulate the tissue outside of the body nullifies this benefit. An endosurgical bag is used for the extraction of specimens from a tiny trocar incision. Cutting the tissue into small pieces in the bag and then removing them is an acceptable technique for some cases, although it is not permitted in cases involving malignant tumors. If a small incision is needed to remove the specimens from the body, the consideration of cosmetic appearance is necessary. An incision along the skin crease at the lower abdomen is preferable (Fig. 3.7). A natural orifice such as the anus can be used for extraction of specimens in some bowel surgery procedures, especially those involving the colon.